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The Magazine of the Arnold Arbor

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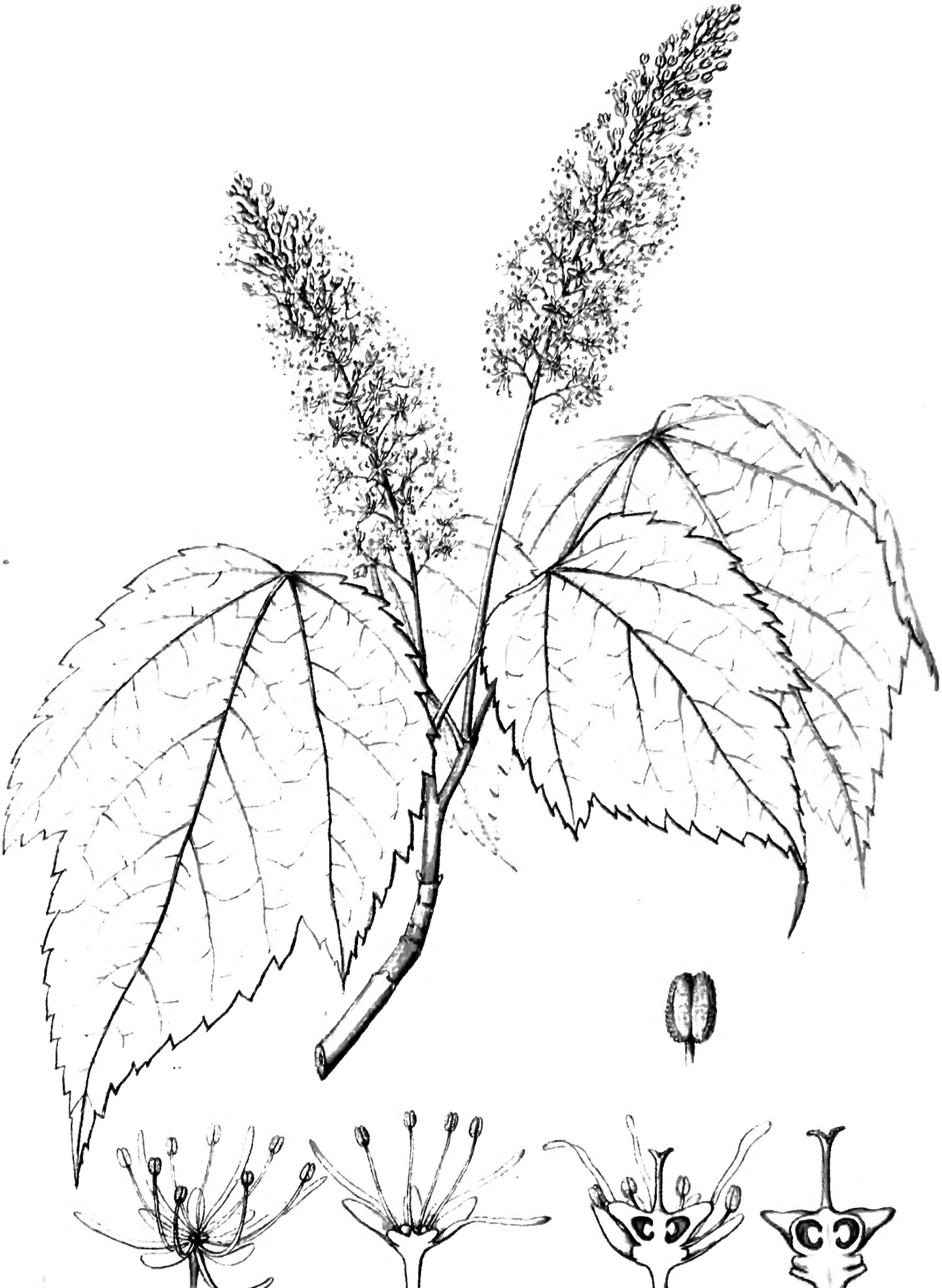

ACER SPICATUM, LAM.

arnoldia

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Front and back cover: Amidst the pandemic, horticulturists at public gardens adapted to "new normal" routines, ensuring that plants in their collections remained healthy. Laura Mele, pictured here, is among the horticulturists who continued to care for the Arnold Arboretum. Photo by Jonathan Damery.

Inside front cover: Charles Edward Faxon illustrated the mountain maple (*Acer spicatum*) for the second volume of Charles Sprague Sargent's *Silva of North America*, published in 1891. "It is now rarely cultivated," Sargent wrote, "although well worth a place in the shrubbery." Arnold Arboretum Archives.

Inside back cover: Eastern cottonwoods (*Populus deltoides*, accession 16611) collected by John George Jack have a prominent location along Peters Hill Road. Photo by Jonathan Damery.

Publication note: Volume 78 will comprise six issues published on the current quarterly schedule. Volume 79 will begin with the first issue published in 2022 and will include four issues.

New Life for Old Collections

Wendy L. Clement

When I first joined the faculty at The College of New Jersey, in 2012, I knew we had a small collection of herbarium specimens available for use in our classes. The specimens were tucked away in the cabinets of the botany lab. At the time, my attention was turned to setting up my lab and continuing my existing plant systematics research agenda, but five years later, a planned renovation of the area where the specimens were kept gave me a reason to sort through these collections more carefully. Upon doing so, my students and I discovered a fascinating story about the origins of this small collection, a more than century-old link to botanical studies in the area, and a reminder of the value of preserving historical specimens that document how plant life is responding to a changing world. Within the collection were nearly 450 specimens collected during the late nineteenth century by three students enrolled in what was then the New Jersey State Normal School. One of the students, Nelson H. Pepper, had collected more than one hundred specimens in the spring and summer of 1892. Some of his specimens were exhibited the very next year at the 1893 Chicago World's Fair, bringing examples of the plants of Trenton, New Jersey, to an international audience.

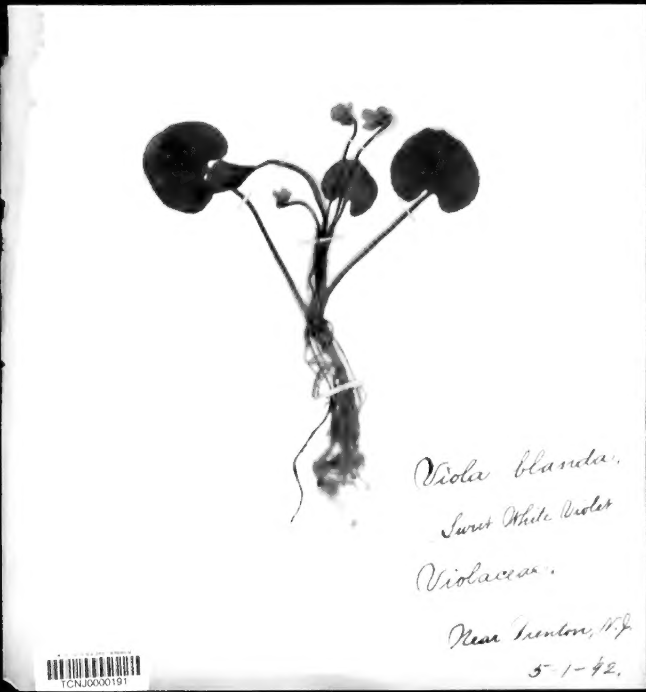
As I pulled out one of the first specimens, I noticed that the unmistakable pink anthers of the spring beauty (*Claytonia virginica*) were still visible under the white petals of the flower. The paper, thinning and stained with a shadow of the plant pressed upon it, could no longer support the weight of this 115-year-old specimen. This page was one of a hundred or more specimens that were kept together by a tattered leather binding. Nelson Pepper's name was still legible in gold print on the spine, along with the word "HERBARIUM." Several folders were loosely stacked in alphabetical order inside the leather cover, each marked with botanical family names. The violet family (Violaceae) was located toward the bottom of the pile, with ten specimens of flowering violets collected in late April and May of 1892. Each plant was pressed and arranged carefully, permitting this set of specimens to illustrate the major differences of *Viola* species he collected in New Jersey. Each heart-shaped leaf of *Viola striata* and each arrow-shaped leaf of *V. sagittata* were separated to show the entire outline of each leaf, and the highly dissected leaves of *V. pedata* were similarly spread across the page. Nectar spurs—short and rounded in *V. cucullata* and long and pointed in *V. rostrata*—extended out the back of the bilaterally symmetric flowers.

The two other books from the same era, compiled by Sarah Elizabeth Kandle and Margaret Todd, also included over one hundred specimens. Our understanding is that all three collectors were completing an assignment for their botany class, led by professor Austin Apgar. In Apgar's more than forty-year career at the college, he was the botany and zoology instructor and, later in his tenure, the vice principal. All the while, he was a strong advocate for the establishment of the New Jersey State Museum. In his book *Trees of the Northern United States: Their Study, Description and Determination for the Use of Schools and Private Students*, published in 1892, Apgar presented a text for educating specialists and nonspecialists alike in botany. In the opening pages, he alludes to his own pedagogical approach of immersing students in studying botany and natural history. "Teach [the student] to employ his own senses in the investigation of natural objects, and to use his own powers of language in their description," Apgar writes. Standing in his place a century later, with twenty-first-century students in my research group, I have continued the tradition of asking students to observe and document various aspects of plant diversity, such as

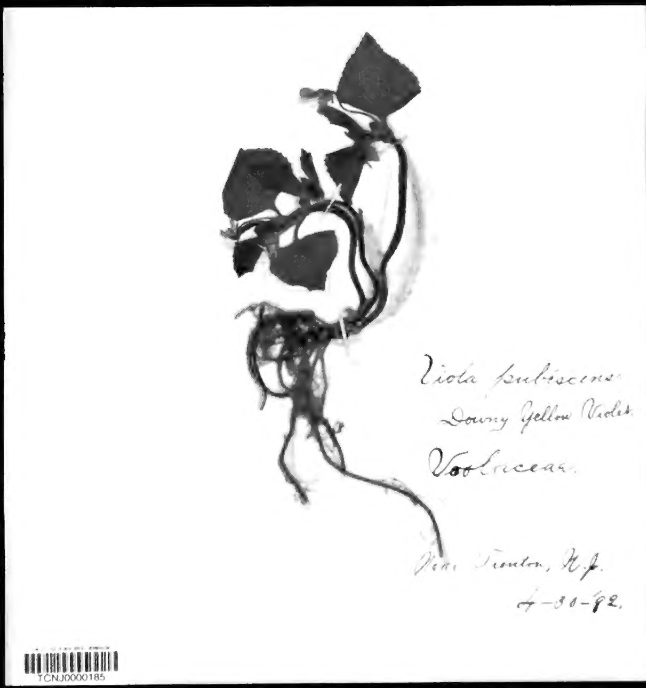
Facing page: **Six of ten violet specimens collected by Nelson Pepper in the spring of 1892. Clockwise from upper left: *Viola tricolor, V. blanda, V. pubescens, V. sagittata, V. pedata,* and *V. rostrata.***

HERBARIUM OF THE COLLEGE OF NEW JERSEY (IMAGES CROPPED)


Viola tricolor
Hearts-Ease
Violaceae.
Decons Bank, Trenton,
5-2-92.
TCNJ0000182


Viola blanda.
Sweet White Violet
Violaceae.
Near Trenton, N.J.
5-1-92.
TCNJ0000191


Viola rostràta.
Long-spurred Violet.
Violaceae.
Lambertville N.J.
May 10, 92.
TCNJ0000188


Viola pubescens.
Downy Yellow Violet.
Violaceae.
Near Trenton, N.J.
4-30-92.
TCNJ0000185


Viola pedàta.
Bird-foot Violet,
Violaceae.
Near Trenton, N.J.
May 3, 92.
TCNJ0000187


Viola sagittata.
Arrow-Leaved Violet.
Violaceae
Near Trenton, N.J.
May 25, 92.
TCNJ0000186

floral morphology or geographical distribution, as they begin to explore possible directions for their own work.

After subjecting our collection to a typical freezing regimen applied to any specimen that has left an herbarium (to eliminate mold or insects), we relocated these books to archival boxes in the single herbarium cabinet in my lab. We then began the careful process of recording information from these specimens, wearing gloves to prevent further damage to the paper. The collection was rather typical of older herbarium specimens, having handwritten labels with little more information than a plant name, collection date, and vague locality. Herbarium labels now regularly include more information documented by the collector, such as detailed descriptions of the plant at the time of collection, robust accounts of the locality and habitat of the plant, and references to co-occurring species. Collectors increasingly include GPS coordinates, especially now that these data are collected with a tap on the screen of a smartphone. Most herbaria are likely to have more-recent, higher-quality collections of the nearly three hundred species documented in our herbarium books. Yet, these historic specimens represent an important snapshot in the history of the landscape surrounding Trenton, which has undergone significant changes over the past century. The specimens offer unique data points for the occurrence of these species and the developmental stage of the plant at the time of collection.

My undergraduate research team often uses herbarium specimens in their work. The College of New Jersey is a primarily undergraduate institution, and at any given time, my lab is comprised of six or seven undergraduates engaged in multi-semester research projects directly related to my ongoing studies in plant systematics. Students working with me begin by engaging with projects that match their interests and then take their investigations in new directions often inspired by their own observations from herbaria or living collections. We are fortunate that our college is located near major herbaria such as the New York Botanical Garden's Steere Herbarium and the herbarium of the Academy of Natural Sciences of Drexel University, which have holdings of 7.8 and 1.4 million specimens, respectively. And now, as a result of major efforts to digitize museum collections, my students can access images of specimens from herbaria across the globe while sitting in the lab. Yet, as my students embarked on extracting data from the historic sheets, deciphering the handwritten labels and updating names to reflect the latest taxonomic changes, this time they had a direct connection to the collectors. In reflecting on their experience transcribing data from these specimens, student collaborators Linda Zhang and Aaron Lee wrote, "Between the faded illegible cursive and yellowed paper we got a glimpse of the lives of collectors and students that spent their time gathering, identifying, and preserving these records with little knowledge that they would be stumbled upon over a century later."

A third student, Matthew Fertakos, came to see this collection as a way to think about how individuals of the same species, divided by time, may change their biology in response to the environment. Matthew had become fascinated with published studies that used herbarium specimens to document how important phases of a plant's life cycle, such as flowering, may have changed over the past century in conjunction with changes in climate. As a DaRin Butz Intern at the Arnold Arboretum, he learned to generate maps that show the predicted distribution of a species based on locality data gathered from herbarium specimens and corresponding climate data for the year the plant was collected. Combining these two interests, Matthew asked what changes were happening in the rare but notable ecosystems of his home state, New Jersey, such as in the Pine Barrens. To date, his work has incorporated over eighteen hundred herbarium specimens, some dating back to the same era as our small collection. Many of the specimens were obtained from the Chrysler Herbarium at Rutgers University, the same institution that generously assisted with digitizing our own small collection. Focusing on a dozen herbaceous species native to the Pine Barrens, Matthew has used these herbarium specimens to generate distribution maps and estimate the first flowering date for many years over the past century. His work continues to test for correlations between changes in first flowering dates and shifts in

Two violet specimens collected by Sarah Elizabeth Kandle in 1894: *Viola pedatifida* (left) and *V. pubescens*.

HERBARIUM OF THE COLLEGE OF NEW JERSEY (IMAGES CROPPED)

climate to understand why some species native to the Pine Barrens now exhibit earlier flowering dates than the century prior.

Matthew's work, inspired by this small collection, joins an ongoing movement that demonstrates the hidden potential of these historical artifacts to provide information about the effects of climate change on a plant's biology. Over the past decade, herbaria worldwide have prioritized efforts to digitize their collections, increasing accessibility not only to botanists but to all scientists whose work could benefit from these data. The renewed life that digitization has brought to museum collections has also allowed us to establish our own herbarium at The College of New Jersey, registered with Index Herbariorum, the international registry for herbaria. Now, our collection, currently focused on historical plants of the Trenton area, will soon be accessible to all. Within this digital collective, our small collection is more powerful than it could have been alone.

The fact that our collection was preserved, waiting for students to use them, was not a coincidence. The families of collectors saw value in these specimens. Rather than ignoring or discarding the specimens among other attic keepsakes, the families donated these otherwise dusty old books of plant pressings back to our department. Now, more than a century after the specimens were mounted and nearly a quarter-century after the collections returned to our department, we are in a unique position to be able to breathe new life into these plants and use them in our quest to understand the effects of climate change on biodiversity, assessing changes that have happened over the past and predicting changes that will happen in the future. The story of how the collections returned to us is a testament to the value and power of amateur botanizing (what we would today call "citizen science") and experiential fieldwork as part of an undergraduate education. As an instructor, I share Apgar's emphasis on engaging students in hands-on observation and documentation of the natural world, and I stress to students the importance of preserving these botanical legacies. Now, the historical plant collections from our region of the country will join the millions of specimens available digitally as the botanical community continues to ask more questions about biodiversity in an ever-changing landscape.

Wendy Clement is an associate professor of biology at The College of New Jersey. She is a plant systematist and evolutionary biologist, and her current research focuses on the evolution of fusion in honeysuckles. She is a current James R. Jewett Prize awardee at the Arnold Arboretum.

Model Maples

Jake J. Grossman

For all of human history and many millions of years before it began, the forests of the temperate Northern Hemisphere have been populated by maples. Today, the maple genus (*Acer*) extends its reach from Guatemala to Canada, the Mediterranean to Scandinavia, and Southeast Asia to the Amur Valley. Like oaks, willows, and birches, among many other genera, the maples as we know them today differentiated from their nearest relatives at a time when the global climate was hotter and wetter than today's and have since survived a long period of cooling and drying, including many ice ages. Their evolution as a genus occurred through geographical radiation across the Northern Hemisphere, interspersed by extinctions and range retractions when climatic conditions became inhospitable.

Contemporary maple diversity is the result of this history and represents only a single, still snapshot from a larger, unspooling reel. The extant maples have adapted, by and large, to climatically temperate conditions: warm summers and cold winters, with occasional dry periods interspersed with regular precipitation. But contemporary, human-caused climate change is rapidly reconfiguring this climate to a warmer one with less regular and more extreme events of rain or snow, making freakish droughts, early arrivals of spring, and warm winters more common. As the climate changes, maples, like other forest species adapted to the temperate north, face an uncertain future.

In my research at the Arnold Arboretum, I make use of publicly available data, existing scholarship, and, most importantly, the Arboretum's collection of over six hundred maple trees (which is nationally accredited by the Plant Collections Network) to predict how the genus will respond to climate change. Specifically, I ask how maple species differ in their response to dry soil conditions and to the shorter, warmer winters that will likely become typical in the Northern Hemisphere. In doing so, I treat maples as a model for other kinds of temperate trees.

The genus makes for a good model for several reasons. First, the maples are highly diverse. The genus consists of 120 to 160 species depending on the taxonomic authority, with half of these growing at the Arboretum. Second, maples have a very wide geographic distribution, unlike some temperate genera confined to only certain continents or regions. And third, as ecologically foundational, long-lived trees, maples are of interest in and of themselves, and so there is an existing body of research addressing their natural history, ecology, and evolution. Yet, in the final analysis, the story of the maples is powerful because it is typical: the genus is neither wildly more nor less vulnerable to climate change than other temperate woody genera. As such, maples can serve as a bellwether for other temperate trees: where goes the maple, so go other temperate taxa. Thus, the genus can tell us about the past, and potentially the future, of northern forests.

Paleogene Origins

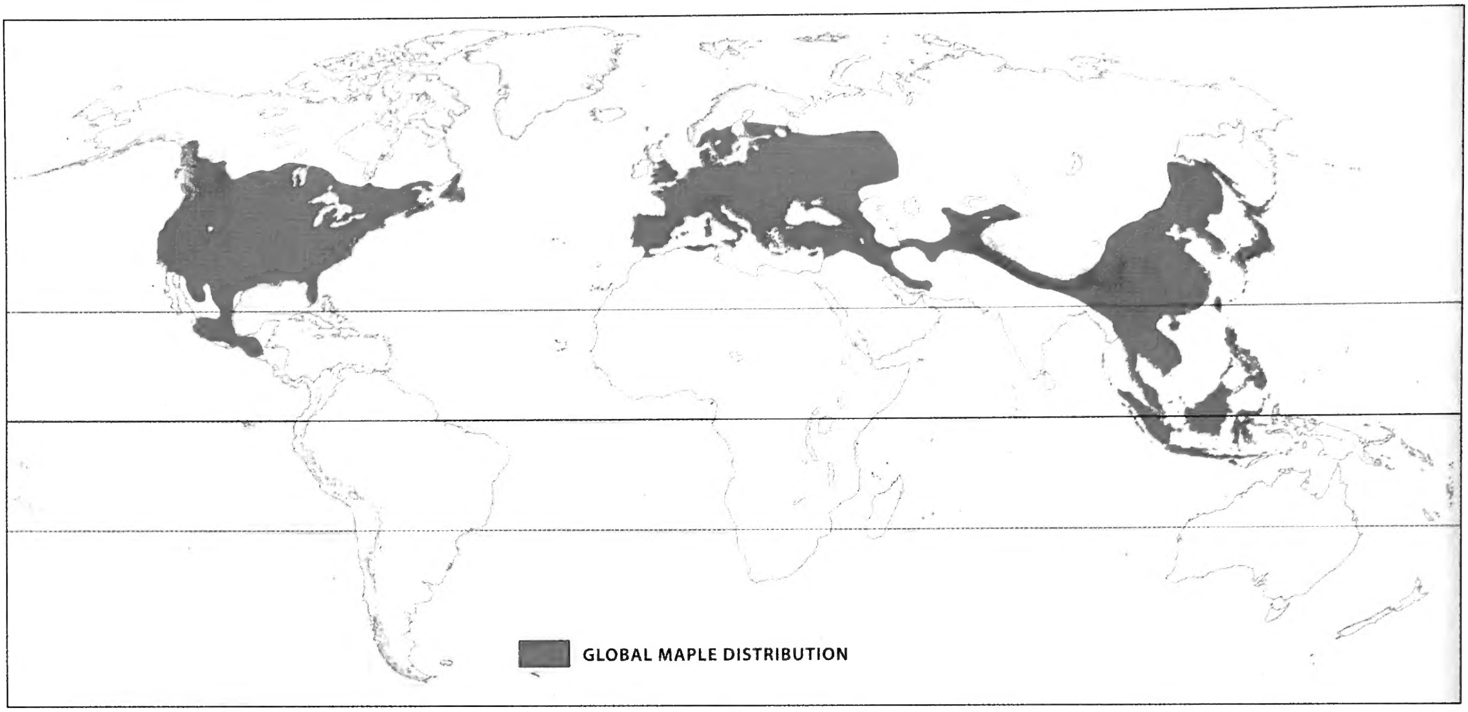
Maples belong to the highly diverse angiosperms, or flowering plants, which probably had differentiated from their ancestors by the beginning of the Cretaceous period, some 145 to 66 million years ago (Coiro et al., 2019). During that period, the earliest flowering plants spread across the globe, competing with and living alongside the previously dominant woody gymnosperms (including pines, cypresses, and ginkgoes). But it was during the next geologic period, the Paleogene (66 to 23 million years ago), that maples split off from their relatives among the flowering plants and truly came into their own.

By the beginning of the Paleogene, the world's continents were more or less in their present locations, although their climates and

Facing page: **Historic maple diversity has arisen over the past sixty million years—a period of extreme climate fluctuations. The physiological adaptations of modern-day maples are therefore a record of that history. The redvein maple (*Acer rufinerve*), pictured here, is native to Japan.**

PHOTO BY WILLIAN (NED) FRIEDMAN

BOTANIC GARDENS CONSERVATION INTERNATIONAL



Maples have a widespread distribution throughout the temperate Northern Hemisphere. This map was prepared for *The Red List of Maples* (2009).

the degree of connectivity among them differed from conditions in the present day. Land bridges between North America and both western Europe (through Greenland) and East Asia (through Alaska) emerged periodically during cooler parts of this climatic cycle and sank back beneath the waves during warmer ones. In general, the global climate was hot and wet: 18°F (10°C) hotter on average than global temperatures during the twentieth century. This means that tropical biomes extended across much of the Earth's land surface, with the poles experiencing temperate conditions like those we now have at the midlatitudes. Ice was absent—or very scarce—on the Earth's surface. As a result, the growth and abundance of plants living at the North and South Poles was probably limited not by cold temperatures but by the scarcity of light (Tiffney and Manchester, 2001).

In these conditions, so different from those we experience sixty million years later, the population of trees that would give rise to the modern maples became distinct from its kin. Per fossil evidence—the appearance of recognizably maple-ish leaves and fruits—and complementary modeling based on the genetics of existing maple species, it was at this point that maples diverged from other genera in the soapberry family (Sapindaceae). This group, which also encompasses horsechestnuts and buckeyes (*Aesculus*) and lychee (*Litchi chinensis*), presently consists of over 130 genera and close to two thousand species. Of these, the maple genus is most closely related to *Aesculus* and to *Dipteronia*, the two extant species of which can be found in mainland China. Indeed, China is likely the evolutionary cradle of maples; despite some fossil evidence that maples originated in North America and spread to Asia over Pacific land bridges, the most recent molecular evidence points to an Asian origin (Li et al., 2019).

From these beginnings in China, maples radiated across the entire Northern Hemisphere while the warm, wet climate of the Paleogene was at its acme. Studies of fossil evidence marshaled by paleontologists such as Toshimasa Tanai (1983), Jack Wolfe (Wolfe and Tanai, 1987), and Harald Walther (Walther and Zastawniak, 2005) indicate that, during this time, the maples were highly diverse and cosmopolitan in their distribution. For example, the maple flora of western North America, for which the fossil record is particularly strong, currently consists of three species: bigleaf maple (*Acer macrophyl-*

lum), vine maple (*A. circinatum*), and Douglas maple (*A. glabrum*). If generous, we could also include in this count the widespread box elder (*A. negundo*) and the western bigtooth maple (*A. grandidentatum*), which is often, and rightly, I would argue, treated as a subspecies of sugar maple (*A. saccharum*). Regardless, Wolfe and Tanai (1987) report paleontological evidence of ninety-one distinct maple species in the region; some of these may be the ancestors of the modern western maples, but the vast majority have been lost to extinction. This pattern, in which current maple biodiversity represents a small subsample of a formerly diverse flora, is perhaps best documented in western North America, but it likely holds true across the maples' distribution. But why?

Maples on Ice

In short, maples can best be thought of as either pitiable victims or, perhaps, resilient survivors of tens of millions of years of adverse climate change. Starting roughly fifty million years ago, the Earth entered a long period of gradual and intermittent global cooling, one we would still be in if not for anthropogenic climate warming. During this time, the poles and middle latitudes became cooler and drier, giving rise to the ecosystems that we now associate with the high latitudes. Permanent ice formed in the Arctic, and glaciers periodically developed and spread south. As a result, maples were pushed toward the equator in some cases and restricted to small refugia—areas of permissive warm and wet conditions—in others. Those species that could not tolerate the increasingly cold and arid climate or migrate away from local, harsh conditions went extinct. At the same time, ice formation and climatic cooling opened up new land bridges. These included not only those among continents but also smaller regional bridges, connecting, for instance, mainland China to Japan, Taiwan, and the bulk of the Korean Peninsula. During these moments of connection, the maples' migration in response to climate change occurred alongside the interchange of previously isolated floras.

Yet the decline of global maple diversity with climatic cooling and drying was not uniform. In general, the last fifty million years have been easier on the East Asian maple flora, which, protected by the geographic diversity and relatively stable climate of the region, now includes the native range of upwards of 80 percent of today's maple species diversity. The maple floras of Europe and North America, on the other hand, have been much more vulnerable to climatic cooling, which has frequently led to considerable glaciation of both continents. However, it is important to note that these cold, dry periods of migration, extinction, and exchange were likely cyclic. As a result, maples, like many other temperate tree lineages, were squeezed and pushed, but then given periods of ten million years or so of relaxed, permissive climatic conditions. During these relaxed periods, populations likely rebounded, beneficial climatic adaptations spread, and species were able to expand from their refugia and southern havens to repopulate the north.

We can see evidence of this pattern if we consider the most recent glacial cycle, alternately referred to as the Pleistocene Ice Age or the Last Glacial Period, which ended eleven thousand years ago. At the height of this Ice Age, glaciers reached well into the northern United States, and much of what we now think of as forestland was probably devoid of tree cover. During this time, sugar maples and box elders migrated deep into Central America, returning north as the glaciers retreated and the climate warmed, rendering their southern refugia too hot and dry and opening up new territory in what is today the United States. As a result, relictual pockets of these maple species can still be found in cool, wet locations, such as cloud forests, in Mexico and Guatemala. This pattern of range shifts and adaptation to new conditions serves as a likely illustration of other maple species' responses to climate change over the last fifty million years.

Classification from Evolution

Against this backdrop of global change and migration, sixty million years of evolution has given rise to our current maple flora of roughly 120 species. (I prefer to stick to a relatively low estimate of maple species diversity. Higher species counts—close to 160 in some cases—treat two maple populations separated by geography but capable of interbreeding as different

species instead of subspecies.) As noted above, the majority of maples (more than one hundred species) are native to the genus's ancestral East Asian home; nine are native to North America; and eleven are native to Europe and Western Asia. Furthermore, a handful of East Asian species are truly tropical, extending into mainland Southeast Asia and Indonesia. Maples are a staple of the Northern Hemisphere's temperate forests, although their ecological role varies from canopy-spanning dominants (sugar maple, *Acer saccharum*, and red maple, *A. rubrum*, in the eastern United States) to specialists that are more sparsely distributed in the understory (moosewood, *A. pensylvanicum*) or generally riparian (silver maple, *A. saccharinum*, and box elder, *A. negundo*). Western botanists since Linnaeus have studied this considerable diversity among the maples (de Jong, 1994). Yet recent advances have finally made it possible to describe the genus in properly evolutionary terms.

For many contemporary biologists, one of the main goals of taxonomy—the classification of organisms—should be the creation of a system in which species are organized according to their evolutionary relationships. In such a phylogenetic approach, species in a given genus, for instance, are all descended from a common ancestral population and are thus more closely related to each other than to other species outside of the genus. This is almost certainly the case for *Acer* as it has been described since the authoritative taxonomy by German botanist Ferdinand Pax in 1885. His work, of course, was carried out shortly after Charles Darwin's proposal of adaptive evolution and many decades before the advent of modern genetics, and so is based entirely on morphological comparisons.

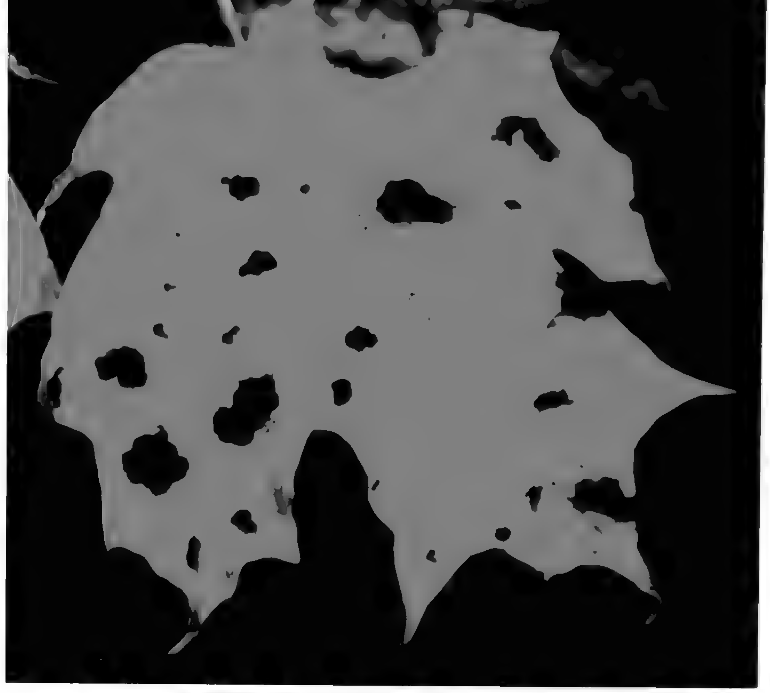
Since Pax, students of the maple genus have continuously refined the organization of *Acer*, proposing and dismissing a variety of schemes in which the genus is organized into sections (each containing species more closely related to each other than to those in other sections) and, within sections, series. For instance, since 1933, botanists have generally agreed that the morphologically similar red and silver maple, both native to North America and unique in their flowering phenology, are members of a distinct section, *Rubra* (de Jong, 1994), with only a single, long-lost East Asian cousin (*A. pycnanthum*). More recently, such classifications have been put to the test through the application of modern genomic analyses.

Most recently, botanist and former Arnold Arboretum senior researcher Jianhua Li, presently at Hope College, has capped off two decades of research into maple systematics by publishing, with colleagues, a definitive phylogeny of the genus (2019). Their portrait of the genus's diversity suggests the existence of sixteen sections, most of which had become evolutionarily distinct by roughly thirty-three million years ago. This point, marking the transition from the Eocene epoch (which began fifty-six million years ago) to the Oligocene epoch (which ended twenty-three million years ago), also coincided with a dramatic drop in global temperatures following a gradual cooling during the Eocene. By the time global cooling preceding our current age had really begun to accelerate, the maple genus had experienced its most profound evolutionary diversification. The emergence, over the subsequent thirty million years, of today's maple species, was likely shaped by smaller-scale adaptations and the extinction of existing lineages, rather than by wholesale innovations within the clade.

So today, after tens of millions of years of evolution, what visible traits define a maple tree? Leaf arrangement and shape, and seed type are probably the best way to identify a member of the genus. To begin with, all of the temperate maples are deciduous and broad-leaved, with opposite leaves setting them apart from many other angiosperm taxa. Most have simple, palmately veined leaves with anywhere from three to thirteen lobes, giving rise to the "maple leaf" shape popularized by the Canadian flag

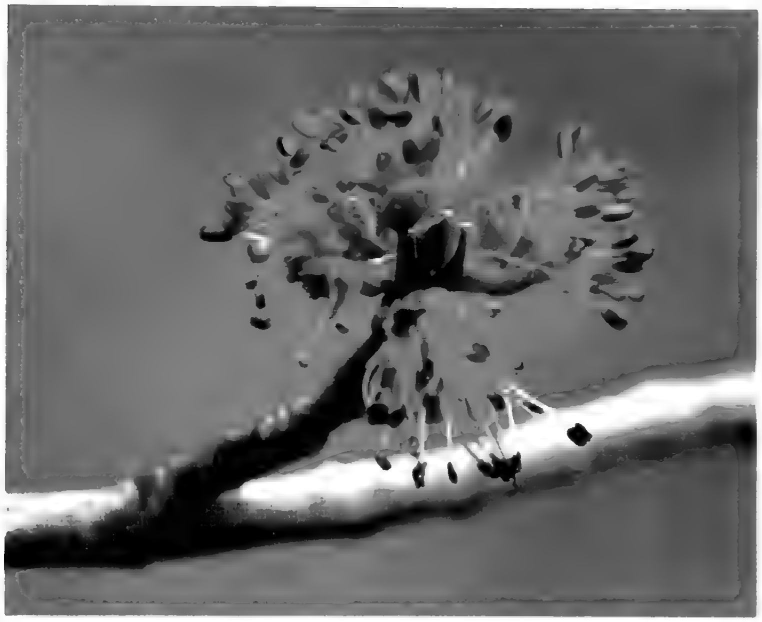
Facing page, clockwise from upper left: **Leaf and flower characteristics of maples are quite variable. The clade (section *Pentaphylla*) with three-flowered maple (*Acer triflorum*) diverged from section *Acer*, which includes the morphologically distinct sugar maple (*A. saccharum*), about 29 million years ago. These groups, in turn, separated from section *Rubra*, which contains the red maple (*A. rubrum*), about 34 million years ago. Although their foliage and flowers are easy to differentiate, horned maple (*A. diabolicum*) and hornbeam maple (*A. carpinifolium*) are in two allied clades. Vine maple (*A. cissifolium*) has leaves that resemble the three-flowered maple, but the vine maple's clade (section *Negundo*) is quite distinct, having separated from its look-alikes about 63 million years ago (Li et al., 2019).**

Acer triflorum



Acer saccharum

Acer cissifolium



Acer rubrum

Acer carpinifolium

Acer diabolicum

and currency, which portray the leaf of a sugar maple—and, in some cases, erroneously, that of an invasive Norway maple (*Acer platanoides*). Yet not all maple leaves fit this rubric. A few species, such as the hornbeam maple (*A. carpinifolium*) bear simple leaves with pinnate venation. And two surviving lineages have developed compound leaves. These species include the North American box elder in one lineage and Arboretum classics such as the East Asian paperbark (*A. griseum*) and Nikko (*A. maximowiczianum*) maples in the other. Furthermore, all maples produce beloved paired samaras: dry, winged fruit that can "helicopter" away from their mother tree when ripe. The presence of a paired samara generally will mark a temperate tree as a maple, though other genera, including ashes (*Fraxinus*), produce unpaired samaras. A tree bearing opposite leaves and paired samaras, then, is very likely to be a maple.

On the other hand, flowers and bark are so diverse within the maple genus as to be unhelpful to most casual plant taxonomists. All maples produce regular, five-part (or rarely four-part) flowers, with fertilized female flowers eventually giving rise to samaras. Yet, here the similarities end. Flowers can be red, yellow, or green, and male or female (though male flowers often bear undeveloped ovaries). Maples can be dioecious—single-sexed—or monecious—having male and female flowers on the same plant. Monecious trees can produce waves of flowers over a single season, going from male, to female, to male again. Few trees, most notably box elder and the horned maple (*Acer diabolicum*), are fully dioecious, meaning they consistently present as either male or female.

Maple bark presents another lesson in the genus's surprising diversity. The scaly motley of green and brown lining the trunk of European sycamore maple (*Acer pseudoplatanus*) makes these trees easy to spot, although in some cases, misleadingly similar to true sycamores (*Platanus*). The bright orange, peeling bark of the paperbark maple (*A. griseum*) is one of its outstanding merits as a horticultural tree. But it is the species of the section *Macrantha*, the snakebark maples, whose green, smooth-to-furrowed bark is, to me, most unusual and appealing. These species are restricted in their distribution to East Asia except for the North American moosewood maple (*A. pensylvanicum*).

Hot and Cold

Despite long-standing celebration of maples' morphological diversity, ecologists still lack a clear understanding of physiological diversity in the genus. I am interested in this question out of the need to forecast how particular species of maples, as well as other temperate trees, will respond to climate change. Recent studies have already documented some climate-related shifts in maple distributions. For instance, in North America, red maples seem to be increasing in abundance, while sugar maples are in decline (Fei and Steiner, 2007; Oswald et al., 2018). But how can these patterns be generalized across the remainder of the genus? Will those species that already live in warmer and drier climates be favored by our warming and increasingly drought-prone anthropogenic climate? Or are species from cooler, wetter habitats secretly concealing a capacity to put up with a wider range of conditions than indicated by their current distribution? In my ongoing study of the climate-change vulnerability of the maples, I seek to answer these questions.

Most temperate forests will experience hotter conditions and a greater risk of drought as our climate changes. What will this mean for the maples? In comparisons of diverse woody plants from across the globe, a few physiological traits have emerged as excellent predictors of how good a given species is at thriving in hot, dry conditions. One of these is *turgor loss point*, the water potential at which a leaf from a tree or shrub loses turgor, or wilts (Bartlett et al., 2012). To date, I have measured turgor loss point for seventeen species of maple coming from diverse sections of the genus and from all over the world.

One pattern emerging from these data is that European and West Asian maples have the lowest (most drought tolerant) turgor loss points, followed by North American and then East Asian species. It appears that species living in the genus's original homeland are among the most intolerant maples of hot, dry conditions. This could be due to differences in the climatic

In the author's research on drought tolerance and cold hardiness, Asian maples, like *Acer ceriferum* (right), tended to be the most vulnerable to severe conditions. European species, like *A. campestre*, tended to be more adaptable, especially to drought conditions.

histories of the maples' East Asian, North American, and European ranges. In Europe, for instance, cycles of glaciation and warming have likely pushed to extinction any species that could not survive dry conditions; East Asia likely contained more refugia, allowing these species, including many maples, to survive to the present (Tiffney and Manchester, 2001).

Yet the perils of hot and dry conditions are not the only challenge that climate change will pose to the temperate maples. Paradoxically, some temperate trees may be at greater risk of springtime freezing damage in a warming climate. The increasing likelihood of *false spring* events, in which warm, short winters allow plants to begin growing again earlier in the year, may lead some trees to lose cold hardiness and sustain critical damage from sudden drops in late winter temperatures. To understand whether maples will be sensitive to false springs, I partnered with my colleague and fellow postdoctoral Putnam Fellow Al Kovaleski, an expert in measuring cold hardiness in woody plants. In these tests, we generally find that maples can withstand much colder temperatures than they are likely to experience in their native habitats—or in Boston!

Many of our test species, even when actively growing, flowering, or putting out new leaves for the spring, can withstand freezing to 14°F (-10°C) or below. It seems unlikely that false springs concomitant with a warming climate will expose trees to these temperatures at the right time of the year and for the periods of time necessary to cause considerable damage. However, in our analysis of cold hardiness across species, we found a continental pattern that echoed my work on tolerance of drought. East Asian species were, once again, least tolerant of cold conditions. But, in contrast to intercontinental differences in turgor loss point, North American species were generally the most cold hardy, with European species intermediate and East Asian species most vulnerable. This is likely due to differences in the way that each continent experiences the onset of spring. Recent

work by a group of ecologists led by Constantin Zohner (2020) has established that North American forests have historically been much more likely to experience freezing temperatures in late spring. European and Asian floras have responded to generally more permissive springs by developing an opportunistic strategy, taking more risks and initiating growth earlier in the spring. As a result, European trees are thought to be in the most danger of damage from false springs as the climate continues to warm.

Back to the Future

But what do these findings mean for the climate-change resilience of maples and, by extension, other temperate woody species? For me, the best way of thinking about the future is to once more turn to the genus's past. For instance, though it's impossible to measure the physiological diversity of the historic European and North American maple floras, we might imagine that, under warmer and wetter conditions, in which environmental pressures were laxer, each region was home to maples adapted to a variety of environments. But paleontological evidence, climate modeling, and the present-day existence of only drought-tolerant European maples and relatively cold-tolerant American species suggest a compelling story.

Successive cycles of cold, dry, and glaciated ice ages during the Oligocene, interspersed with warming, may have weeded out those species sensitive to these environmental stressors. This mechanism has been suggested to explain the relative lack of diversity in temperate eastern North American and Eurasian forests relative to those in East Asia and western North America (Qian and Ricklefs, 2000; Svenning, 2003). And they certainly explain patterns of physiological and species diversity for the extant maples outside of East Asia. Perhaps the few remaining species in North America and Europe are those that have managed to survive, adapt, and migrate in response to glaciations and accompanying cold and dry conditions. Pushed into Meso- and Central America and into Northern Africa, they have subsequently returned to higher latitudes, becoming locally abundant in the case of widespread species such as sugar, red, Norway, and sycamore maples, among others. Differences in the geography and climate of each continent have only reinforced these adaptive patterns: North America, for instance, has more extreme and variable early spring temperatures, producing a more cold-hardy flora (Zohner et al., 2020). But what will happen next, as our climate warms and patterns of precipitation become more erratic?

We could be facing a future reminiscent of our past, but with a twist. Paleoecologist Kevin Burke and colleagues, in 2018, offer a particularly compelling illustration of how global change might affect Earth's temperate forests. In this modeling exercise, the authors compare likely scenarios of future climate change to what we know about the Earth's historical climate based on climatological reconstructions. Disturbingly, they predict that, under a business-as-usual scenario, in which humans do nothing to curb climate change, the Earth very well may, by 2200, have a climate akin to that of the Eocene period (roughly fifty million years ago in their analysis). This means that, in just seven maple generations, we may skip over fifty million years of changing climate, reverting to conditions similar to those *before* the diversification of the maple clade in the late Eocene and early Oligocene. Whether our current palette of maple species can tolerate these conditions is unclear.

Our warming climate could open up some habitat, at least initially, for cold-tolerant and northerly distributed maples (like sugar maple and Norway maple) to extend further into areas that are presently too cold for trees to inhabit. And maybe the highly drought-tolerant species of Eurasia will be able to capitalize on drying and warming conditions to displace more-mesic species. But there is also a likelihood that anthropogenic climate change will create what climatologists call *no-analog* conditions, a climate unlike one that our existing flora and fauna have ever experienced, much less adapted to. In this case, humans will truly face something new under the sun, as will our biotic companions. In the immediate future, the story of the maples suggests the critical need to begin the conservation of woody plants we know to

be heat- or drought-intolerant. These conservation efforts include the *ex situ* migration of species out of their current native ranges. We also should begin investing in forestry that focuses on those species that, by virtue of their natural history, have proven themselves capable of withstanding long periods with limited access to water.

These suggestions, based on the climate-change vulnerability of the maples, are meant to apply to a variety of temperate woody taxa, including oaks, willows, and birches. Each of these genera is the result of a complex set of journeys across multiple continents and survival over many millions of years of global change. That such adaptation is possible should at least give us hope for the work ahead of us to keep the planet livable, both for our own progeny and for whatever comes next in the story of the Northern Hemisphere's forests.

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FORREST, T., GALLIGAN, B., GOTT, R.C., GUIDARELLI, C., HENRICHSEN, E.T., HUANG, T., KARTES, N., LAPLUME, G., LOVING, S., MERRIAM, D., SALYARDS, J., SHEARER, K., AND WILLIAMS, K. 2020. ESSENTIAL GARDENING: PUBLIC GARDENS IN THE SPRING OF COVID-19. *ARNOLDIA*, 78(1): 16–31

Essential Gardening: Public Gardens in the Spring of COVID-19

Todd Forrest, Brian Galligan, Ryan C. Gott, Conor Guidarelli, Esther Truitt Henrichsen, Terry Huang, Nancy Kartes, Greg LaPlume, Sharon Loving, Debbie Merriam, Jim Salyards, Kim Shearer, and Kevin Williams

The spring of 2020 has been defined by upturned plans. As the number of COVID-19 cases skyrocketed, lives across the United States were reconfigured. Eight-year-olds learned how to take school classes remotely. Grocery stores began limiting the number of shoppers who could be inside at once. Restaurants reinvented their menus for takeout. Businesses large and small closed their doors, sending millions of workers to unemployment. Even hospitals—while stretched beyond the max on one front—began furloughing employees, given that routine and elective appointments were canceled. Streets in cities like Boston became veritably empty, with no morning rush, no evening rush.

Public gardens, like other cultural institutions, were confronted with the same stay-at-home mandates that shuttered their communities. According to the American Public Gardens Association, more than 25 percent of gardens closed on a single day (Monday, March 16), and by the end of March, only 4 percent remained fully open to the public. The plants, of course, did not wait to begin growing until gardens reopened. The sunshine-colored blossoms of forsythia and daffodils put on their radiant shows no matter what.

The unrelenting arrival of spring was, in many ways, incongruous with the national mood. It also meant that horticulturists at public gardens continued working despite closures and event cancellations at their institutions. Schedules changed. Procedures changed. But there were plants to be tended. Below, thirteen horticulturists from gardens around the country describe the on-the-ground realities of caring for their collections during the first months of the pandemic—the months in which an old normal faded and a new normal was created.

January 24

On January 21, 2020, our nation's first case of COVID-19 was reported in the Seattle area, just a few miles from Bellevue Botanical Garden. I was not paying attention to the news. As garden manager, I was deep into planning our first big event of 2020: a Lunar New Year Celebration scheduled for February 2. We had been snowed out the year before, which would have been our first year celebrating this event, so excitement was high over the favorable weather forecast. We expected over one thousand visitors. I could imagine red-and-gold lion dancers snaking through entry gardens that would be redolent with witch-hazels and sarcococca. The hot pink blossoms of *Camellia* 'Mary Christian'—evocative of the tea plant (*C. sinensis*)—would be punching through the winter gray.

One of our community partners, Lily, began each planning meeting by serving different varieties of Chinese tea. Her gracious habit kept me connected to the mission of our collaboration: teaching the public about botanicals used in Chinese teas. Lunar New Year was to be the first of four events celebrating Chinese tea arts through the seasons. At our pre-event check-in on January 24, Lily was visibly shaken. She was wracked with concern over the news out of China. She had been in touch with friends and family there and felt it would be disrespectful to hold a large public celebration at a time when so many were suffering. She and her colleagues feared the virus would spread here. I

***Facing page:* Horticulturist Jessica Kaplan cares for the New York Botanical Garden's Native Plant Garden.**

PHOTO BY THE NEW YORK BOTANICAL GARDEN

agreed to cancel the event out of respect for the Chinese community. At the time, I didn't think it was necessary to add "out of an abundance of caution." It was a scramble to put the brakes on with just a little over one week's notice: cancel the lion dancers, the musicians, the tea ceremonies. Notify the public, the volunteers, the dignitaries.

While our garden was deep in winter dormancy, with so much unseen beneath the surface, novel coronavirus was silently making its way through our community. Our area was destined to be the first epicenter of the outbreak in the United States. Events and programs fell like dominos, one after the other as our understanding of the pandemic evolved, until our governor issued a stay-at-home order and everything ground to a halt on March 25. Our facilities closed. A handful of crew members would continue coming in to care for the garden, which remained open for walking, free as always. Everyone began panic shopping for toilet paper, which I could not understand. I stocked up on veggie seeds and compost.

On January 24, I didn't see any of that coming. I now feel haunted by that day, by my ignorance in thinking that the virus was far away, not our problem. Thanks to our Chinese friends, we made the right call and that decision may have saved lives. I remember that we, at Bellevue, are the lucky ones: no staff layoffs, volunteers eager to return, and all of them healthy. I remember that we are strong and resilient. And I remember that, in the garden, the hidden promise of winter dormancy burst into an early spring, with daffodils, daphne, and rhododendrons coming into bloom, each, in their turn, providing respite from pandemic fears.

—*Nancy Kartes, Garden Manager*

March 15

I was at home on Sunday, March 15, when we decided to close the New York Botanical Garden indefinitely to the public and nonessential staff to help prevent the spread of COVID-19. For several weeks prior to this decision, we had been following the news of the virus, communicating regularly with various government agencies, and planning for at least a partial shutdown. In spite of our preparation, the decision to close the garden at the height of our annual *Orchid Show* and on the eve of spring felt nonetheless sudden and severe. Even though we had dealt with temporary closures after 9/11 and during various hurricanes and blizzards, none of us had ever experienced a long-term shutdown with no clear path to reopening. Gardens shouldn't close in spring.

Starting at about seven o'clock that evening, I set out to call every member of the garden's horticulture team (nearly seventy people in all) to relay the news and to assemble a small crew to come in the next day. With 250 acres of designed gardens and curated plant collections and two glasshouses, the New York Botanical Garden needs tending every day. Fortunately, New York State deemed us an essential business, which made our horticulturists essential workers. Unfortunately, due to social distancing protocol and budgetary concerns, we could only bring in a reduced staff on an intermittent schedule.

By ten o'clock, I had reached everyone and had confirmed twelve staff for the next day. Even as I grimly delivered the news of the closure to one colleague after another, I was buoyed by their hope and desire to help however they could. Hope in the face of COVID-19 was no small thing. At the time, none of us knew how severe the pandemic would become, but all of us were aware that New York City, with its densely packed humanity, could be fertile ground for a highly communicable virus. Many of my colleagues live in the five boroughs and take public transportation to the garden. Many are in close contact with elderly parents, or have partners with respiratory conditions, or care for small children, or have some other legitimate reason to be especially scared of contracting COVID-19. Despite their personal concerns, the horticulture staff knew what was at stake and gamely signed up to come in. They understood the essential nature of their work keeping the New York Botanical Garden healthy and beautiful so the garden can achieve its mission of serving and delighting the public.

This spring has taught me a lot about the profound impact our garden has on peoples' lives. It has also deepened my respect and gratitude for the professional horticulturists who

At the Arnold Arboretum, in-person horticulture meetings have shifted to Zoom. Here, horticulturist Conor Guidarelli attends from the landscape.

care for our collections, displays, and natural landscapes. These are New York horticulturists: a bit jaded perhaps, and suspicious of authority (e.g., me), but as tough and serious as they come. Many have worked here for decades and are deeply proud of what we have built together on the foundation laid by the generations of horticulturists who came before us. And so, through the height of the pandemic, our now officially essential horticulturists came to the garden, albeit on significantly reduced and altered schedules, to care for our plants, COVID-19 be damned.

—Todd Forrest, Arthur Ross Vice President for Horticulture and Living Collections

March 17

On Tuesday, March 17, I was in the nursery at the Arnold Arboretum with five other horticulture staff, digging trees and shrubs for the spring planting. It was the day after buildings at the Arnold were closed to non-essential personnel. Originally the closure was described as a "trial" work-from-home week, but for most, it would become a new normal. Horticulture staff would also set up home offices to reduce essential staff densities. Those who were juggling work, parenting, and teaching duties were home first. Our team in the nursery was the only horticulture and greenhouse staff on site that day.

The nurseries consist of three plots that are tightly spaced around the greenhouses, located on a central edge of the landscape. Visitors can see the nurseries and greenhouses through a chain-link fence. Almost all the one hundred plus trees and shrubs that were slated to be dug this spring were growing in a single nursery plot, and everything was to be balled-and-burlapped. This method involves hand digging a teacup-shaped mass of roots and soil (the children's song "I'm a Little Teapot" always runs through my head) and lacing sisal in an inter

woven drum-like fashion to hold on a covering of burlap. One person can do the digging and burlap dressing, but it takes at least two to hoist the plant to the surface. We managed to keep several feet away from one another by lifting with ball-and-burlap straps. At that point, we were all wearing makeshift masks fashioned from cotton rags and handkerchiefs.

We normally dig several specimens and then go out onto the grounds to plant them on the same day. This spring, however, everything was to be dug at once. Given the small size of the nurseries, space is constantly in demand. New seed arrives from plant-collecting expeditions every year, and the seedlings work their way into the greenhouses, to the shade nursery, and eventually either into containers or into one of the nursery plots. If plants were not dug from the nurseries it would stop the production line. Because many of the plants are collected in the wild, throwing out the inventory is not a choice. The plants are impossible—or exceptionally hard—to replace. These are not mass-produced Knock Out® roses.

When the coronavirus was first being reported in the United States, back in January, I was grimly aware that the pathogen would be exceptionally disruptive. In our horticulture meetings, we began creating a game plan for how we would prioritize our operations under a series of scenarios. The fourth scenario was a near shutdown of operations, with only one or two people on-site. As it ended up—and as I worried would happen—we went straight from the modest precautions of the first scenario to the intense shutdown of the fourth within a matter of weeks. Before scenario four could occur, however, spring planting had to be completed. We had initially planned to tuck the balled-and-burlapped plants into another space in the nursery for a fall planting, but halfway through, the plan would shift: everything would be planted, including another two-hundred-odd plants that had been grown in containers.

From the nursery, we could see through the fence to the main roadway that winds through the Arnold, which offered a view of a tremendous influx of visitors. The landscape is free and would remain open despite other closures. It is tucked directly within Boston residential neighborhoods, and with businesses around the city sending employees home—or worse, laying off workers—wave after wave of visitors were taking midday walks in the landscape. It felt like everyone was arriving for our largest event of the year, Lilac Sunday, but the lilacs were still more than a month from blooming. Tree branches were still bare and leafless. But our relentless pace of digging continued. This task was essential.

—*Greg LaPlume, Arboretum Horticulturist*

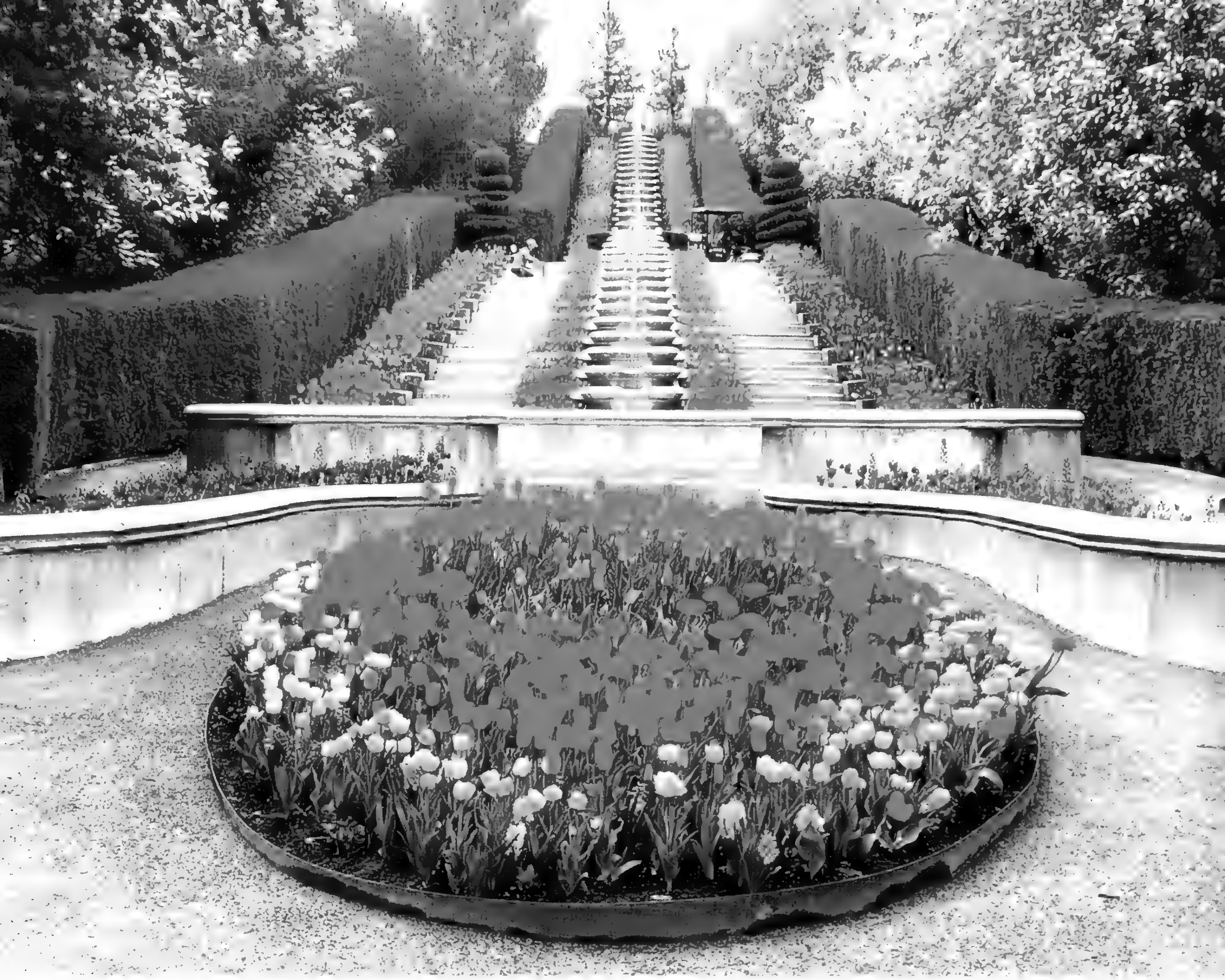
March 25

In the early days of the pandemic, the pervasive singing of birds at Filoli was uncanny. The garden is nestled in the mountains between the San Francisco Bay and the Pacific, halfway between San Francisco and San Jose. While the gardens are formal—part of a sprawling estate that was established on gold-mining profits more than a century ago—wildlife is always abundant. Birdsongs provide a sense of vibrancy during the day, and large animals (like cougars, coyotes, foxes, and raccoons) leave evidence of nighttime visits. On March 25, I was in the Sunken Garden, snapping a social media photo of yellow 'West Point' tulips that were blooming within the low, clipped hedges of the *parterres*. The calls of sparrows, towhees, crows, and finches were inescapable, but they were now an eerie reminder of the lack of human voices in the garden. Filoli had closed the week before, on March 17, and although the horticulture team would continue to care for the landscape, the garden had to lay off some of our frontline staff at the beginning of our closure. Wildlife was becoming more brazen in their activities, but it was very bittersweet when all who would normally be enjoying the garden, along with the birds, were missing.

Filoli has blooms 365 days a year because of the moderate climate along the coast of northern California. Camellias and daphne begin blooming in January. In summer, the formal *parterres* showcase a bounty of colorful designs. But spring continues to be our biggest draw. Locals and visitors from around the globe are captivated by the spring experience of seeing

'West Point' tulips at Filoli Historic House and Garden.

PHOTO BY JIM SALYARDS



At Ashton Gardens, a horticulturist cuts tulips from the Italian Gardens for online sales.

daffodils and tulips in our meadows and formal beds. Wisteria clambers on the side of the mansion, and peonies are showstopping. But this year, our spring peak of mid-March to mid-April was completely missed. All the planting and tending on the part of the staff, all the expectant calls and emails that started at the beginning of the year asking the best time to visit were for naught.

I did my best to share photos and videos through our social media outlets, but it's just not the same. A few thumbs-up or heart emojis are a poor substitution for the "oohs" and "aahs" and the thank-yous we receive from guests each day—the guests who call out compliments while we are weeding and pruning or who pass along the praise to our colleagues in visitor services and interpretation. Public gardens like Filoli are champions of environmental education and conservation, yes, but we also provide substance for people's souls. Hopefully, in the near future, the garden will once again become a space of healing, just when the world needs us most.

—Jim Salyards, Director of Horticulture

April 6

The first week of April, three weeks after Utah went on voluntary shutdown, I spent two beautiful days pruning at Ashton Gardens where I work. The gardens were closed to the public, and the gardeners were "social distancing," a term that was new to our everyday vocabulary. I was on my own, pruning and listening to music within the walled Secret Garden, an enclosed space among the designed ruins of gothic arches that drip with honeysuckle (*Lonicera japonica* 'Halliana') and Virginia creeper (*Parthenocissus tricuspidata*). As the garden designer, I don't often have a chance to work directly in the

gardens, but during the pandemic, the entire staff was stepping up to help with horticultural care. I love to prune. I worked my way through the collection, shaping and thinning shrubs. I pruned branches from an indecisive willow-leafed pear (*Pyrus salicifolia* 'Pendula'), removing those that were sticking straight up and keeping those that were draping down. It was just me, the blue skies and sunshine, and ten thousand tulips in the Secret Garden—yes, ten thousand of the quarter million that we had planted at Ashton Gardens for our annual Tulip Festival. Like so many things this spring, the event did not happen, so only the gardeners and the birds were there to see the show.

Ashton Gardens lies thirty miles south of Salt Lake City in the foothills of the Wasatch Range. We are part of Thanksgiving Point Institute, a complex of gardens, a farm, and museums in the middle of a rapidly developing area called Silicon Slopes. The Secret Garden is one of our guests' favorite spaces within our fifty-five-acre landscape, and its charm lends itself as a place to stage marriage proposals, as well as for meetings of the local crochet club. There were no marriage proposals in the gardens this spring. Utah went on voluntary lockdown on March 14, before the gardens officially opened for the season. The office staff of Thanksgiving Point mostly worked from home, and staff with service jobs were paid to stay home. Due to our ability to distance ourselves while working, the garden staff had the good fortune of continuing to work every day.

On March 18, four days after lockdown, a 5.7-magnitude earthquake hit the Wasatch Front. I was in my office and, true to my elementary school earthquake-drill training, dove under my desk. The staff working outside in the gardens didn't even feel the quake. Over the next several weeks, over two thousand aftershocks occurred, and COVID-19 was always there just beyond the garden gates. While we worked in the gardens, nature helped us to find solace in the storm and feel less unnerved than many in our community. Throughout the weeks that would have been the Tulip Festival, we cut fifty dozen tulips from the garden each day. Thanksgiving Point members could preorder bouquets and have them delivered to their front porch. Or they could drive past the Ashton Garden Visitor's Center, pop the hatch so that garden volunteers could put the flowers into the car, and then drive away with their little bit of the Tulip Festival.

—*Esther Truitt Henrichsen, Garden Designer*

April 13

On Monday, April 13, I was at the Mary May Binney Wakefield Arboretum, located just south of Boston. As the arboretum director but one of just four employees, I normally work in our gardens every day. It's a twenty-five-acre property, listed on the National Register of Historic Places, and we are recognized for our collection of more than three hundred kousa dogwoods (*Cornus kousa*). The dogwoods were grown from seed that Mary (Polly) Wakefield collected at the Arnold Arboretum, where she took propagation classes for more than forty years. Our grounds had officially closed to the public following the statewide stay-at-home order that went into place on March 24. Due to the size of the landscape and staff restrictions—one week on and one week off—I had only seen my coworkers in passing and felt so fortunate to still be employed, working in the garden that had become such a place of peace and solitude.

On that day, however, pouring rain kept me inside catching up on paperwork. In an effort to create distance between staff members, I had moved my office from an old farmhouse to the main historic residence: a 1794 Georgian mansion. As the rainy and blustery spring day progressed, I looked out of the windows of the antiquated kitchen where I had set up my workstation and observed several of our massive hemlocks swaying back and forth. Mature trees before the Civil War, these hemlocks withstood the 1938 hurricane that destroyed many native trees all over New England. More recently, these giants survived hemlock woolly adelgid with attentive care. As winds strengthened, I received an alert from the Blue Hill Observatory, just a mile away, that gusts were recorded at eighty miles an hour. I heard a loud crack and saw that a large limb had come down and obliterated our ten-foot privacy fence. I stepped out of the mansion to survey the damage and quickly realized it was not a good time to be

standing among so many towering trees: hemlocks, sugar maples, and red oaks that are the oldest in our collection. Instead, I locked up the mansion, hopped in my car, and headed toward the gate and home.

Ten minutes later, the largest hemlock snapped about ten feet up and with its huge girth took another massive tree with it, narrowly missing the mansion. I received an alarmed text from my colleague saying, "We lost the big ones." I could not fathom these trees falling until the images appeared on my phone. It seemed almost cruel that these hemlocks would no longer record history from their stately position. As a wave of sadness came over me, I recalled a moment standing in an ancient hemlock grove in graduate school, listening to Mark Ashton, my favorite forestry professor. He spoke with deep passion and amazement about the hemlock's ability to survive in the understory for hundreds of years, biding their time until one of their cohorts comes down leaving growing space for a young tree to continue the legacy. Perhaps this would be an opportunity to plant some of the Chinese hemlocks (*Tsuga chinensis*) that I had been raising in our nursery. Or perhaps a young self-sown hemlock seedling would rise within the gap and thrive. I took great comfort in the fact that plants are so resilient and will go on, as will we in this challenging time.

—Debbie Merriam, Arboretum Director

April 15

One morning, around April 15 (time has lost a lot of meaning during quarantine), I came into work at Phipps Conservatory and Botanical Gardens to a desk covered with plant samples. As the associate director of integrated pest management, I handle our plant health care, including the diagnosis of all pests and disorders and the prescription of management and scouting protocols. I typically expect interesting new mysteries to appear. But looking through these samples, my first thought was, "These are all known issues. Why were they turned in?" Then, it hit me. Of course. With our new coronavirus-altered schedules, horticulturists were caring for spaces and plants they never had before. Everything they encountered was new to them—the day-to-day simply didn't exist anymore.

While gardens may not have been deemed officially life-sustaining during quarantine, we certainly are in the business of sustaining life—plant life that is. Phipps, located in Pittsburgh, closed to the public on the afternoon of March 14 due to COVID-19. While our glasshouses—a mixture of original Lord & Burnham Victorian-style rooms from 1893 and some modern additions like our Tropical Forest Conservatory—were shuttered to visitors, our plants still needed attention. Before coronavirus, horticulturists managed specialized areas including production greenhouses and collections of palms, ferns, orchids, cacti, bonsai, and more. During the coronavirus closure, we had large changes to our team structure. Instead of furloughing staff, we reorganized our horticulture department into three small teams that rotated on-site coverage on continuous five-day schedules starting March 27. All other Phipps staff worked from home, including horticulturists during the off-site portion of their rotations. This meant horticulture staff cared for more spaces than they typically would, often outside of their plant specialty. Pieces of our pest management plans, such as syringing this or that palm to suppress spider mite populations, were not always tended to since staff were working hard to perform basic plant life support like watering over large areas. These sorts of pest management tasks that were second nature to a room's usual horticulturist were unknown to other staff.

In normal times, a handful of volunteers are at Phipps nearly every day, helping horticulture staff pot plants, clean beds, sow seeds, and more. One volunteer comes in every week to help me by scouting greenhouses for pests, carefully washing and cleaning plants to manage insect issues, and collecting samples of leaf spots and rusts. Like the other volunteers, she has not been on-site since we closed to the public, and without her, these simple but time-consuming tasks fell by the wayside. On May 3, according to my notes, I was finally able to check a particular cycad that my volunteer would regularly clean but that hadn't received her attention in almost two months.

The poor plant was overwhelmed with mealybugs, its newest set of growth fuzzy with wax and deformed and stunted from the mealybugs' toxic saliva. I cleaned it, arranged for augmentative biocontrol releases, and even identified some wonderful brown lacewing predators that were already present, feasting on the mealybugs. I, and all our staff and plants, are really missing our volunteers.

Integrated pest management and plant health care more broadly are team efforts. As we adapt to whatever our new daily "normal" will look like, I've come to see how cross-training staff in many areas would produce knowledge and skill redundancy in all aspects of plant health care. Colleagues at other gardens have had similar realizations. These and other conversations and innovations will move gardens forward and better prepare us—and our plants—for whatever the future may hold.

—Ryan C. Gott, Associate Director of Integrated Pest Management

April 20

The headhouse sits at the southern end of Filoli, among the greenhouses, nursery, and a few oaks. Inside, the air was cool and faint with the soft scent of aged cement and redwood. Working in the dim light, I slowly organized my desk. My fellowship had ended early due to the pandemic, and this was my final day. I sorted through the years of accumulation drawer by drawer, encountering fragments of the many lives that had passed through here: a handwritten reminder, a hair tie, a playing card, a dead spider. My mind drifted as I worked. I had been working off-site for a month and a half, and my last memory of the garden was in early spring. The hellebores and magnolias had just given way to a few blousy spring camellias, but most of the garden still slumbered. While my life took a pause, the strengthening sun and late spring rains had coaxed the garden out of its winter dormancy. Now, the fresh green growth of redwoods, coastal oaks, and arbutus enrobed the Santa Cruz Mountains. Irises and tree peonies stretched their satiny crepe petals in the spring sunlight. Masses of tulips swayed cheerfully in the gentle breeze as voles darted between their beds. With so many flowers in bloom and no one to admire them, the garden was rejoicing, blooming for itself without judgement. A little space to breathe, a moment to grow.

After labeling the stacks of important documents and wiping down all surfaces, I headed out to the staff vegetable garden. Tucked away behind the headhouse, the garden is protected by a tall cherry laurel hedge and brick wall. The winter crops had finished. I saw evidence of recent activity, but not a single soul was there. Future plots were weeded, tilled, and enriched. Rows were marked and irrigation laid waiting. Soon rows of tomatoes would glisten in the sun, their leaves releasing a resinous fragrance. Swollen squash would hide under their giant prickly leaves. Multicolored carrots and potatoes would be unearthed like crystals and geodes, while sun-warmed strawberries and bright lemon verbena perfumed the air. The abundance would provide more than enough for human, beast, and microbe. For me, this was a place of refuge that had sustained me for a year, a place where I cultivated community with the earth and between people. I will miss the way the soil crumbled in my hands and how laughter floated over the garden hedge. Walking down the gravel path one last time, I took in the peace before heading out through the garden gate.

—Terry Huang, now Assistant Director of Mildred E. Mathias Botanical Garden at UCLA

April 30

I dragged my eyes away from yet another Excel spreadsheet to the tall casement windows in my office. From my vantage at the northwest corner of the Horticulture Building at Longwood Gardens, I could see threatening clouds lumbering towards me. Located forty miles southwest of Philadelphia, Longwood doesn't normally receive such severe weather in late April. The sky darkened in minutes and began hurling something between hail and enormous raindrops into the windows, blurring my view of the forest edge across the deserted employee parking lot. The forecast was for a straight-line wind, but the tree branches were swirling in circles. The tops of the tall oaks and tulip poplars swayed in an unnatural dance.

It was late on April 30, and six weeks had already passed since the mandatory closure

of our doors. Like the closures at many other gardens, this prolonged shutdown has been a first for Longwood. Even after a long career, I had found myself making the most challenging decisions I have ever had to make—reducing budgets, furloughing all of the part-time staff, preserving our precious and rare plant collections—all within the span of a few weeks. We had already removed thousands of plants slated for our spring display, ripping out hundreds of beautifully planted beds of tulips and lilies. Our greenhouse staff had meticulously grown *Echiums* for a full year, and although the plants were magnificent, towering at four feet high, they never made it to display but instead were diverted to our compost stream, along with thousands of other crops. For a gardener, shuttering such beauty is heartbreaking. I hadn't expected to have such an emotional response to all of this (after all, they're only plants). Musing about the challenges being faced by our communities and our nation, I chided myself for being selfish. Our losses were only short-term.

Watching the wind and rain, I suddenly heard a loud, splintering crack followed by an earthshaking crash. I squinted through the gray deluge and could see an enormous oak was missing from the skyline. Shortly after, the phone rang and a colleague delivered more bad news: a precious tree, the oldest *Magnolia acuminata* var. *subcordata* 'Peirce's Park' in the garden, named for the historic site on which it was planted, was down.

This cucumber magnolia, at over eighty-five-feet tall and with a mighty girth of four-feet, was a national and state champion. We had traced the lineage directly back to French explorer André Michaux, who discovered this species in South Carolina in 1788. Planted between 1780 and 1830, this tree was part of a mature alleé of trees (considered to be the "Soul of Longwood") that the Peirce brothers had established on the property. Garden staff have even speculated that John Bartram or William Hamilton had helped them procure the tree, as they had in their own gardens in Philadelphia. Our founder, Pierre S. du Pont, purchased the original farm that was to become Longwood to save these trees from being lumbered.

It was too dangerous to check the tree that night. The following morning, breezy and clear skies laid bare the torn twigs and stripped leaves strewn across the paths and lawns. I kept walking; I have become better at ignoring the lack of perfection these past months. Normally the entire horticulture team would be scouring the landscape picking up every bit of debris—but not today.

Seeing the tree down reminded me of an image of a poached elephant I had seen years ago: gray, lifeless, enormous, and sprawled awkwardly across the path. I ran my hands over the tree's scaly bark, gave it a hug, and said goodbye. On my way back, grief gave way to a fleeting thought of hope. Almost twenty years ago, we propagated saplings from this tree. I walked past three of its progeny that were battered and dazed but still standing strong: future sentinels at the opposite end of the same alleé the Peirce brothers planted more than two hundred years before.

—Sharon Loving, Vice President of Horticulture

May 8

On Friday, May 8, I received a text message from Erin Bird, our communications manager.

"Are the lilacs blooming?" she asked. I knew she was looking for social media content.

It was a welcome text. I missed these interactions. I hadn't seen or heard from many of my coworkers since the Denver Botanic Gardens closed on the afternoon of March 16. Thankfully, none of my colleagues lost their jobs, but only staff considered essential to the stewardship of the facilities and living collections were on campus, so the space felt different, quiet, empty.

"They are blooming, but not very well ..." I responded.

Denver sits in the rain shadow of the Rocky Mountains, on the eastern edge of the North American steppe, the expansive semiarid grasslands and shrublands characterized by hot summers, cold winters, mineral soils, and very little water. Echoing the mountains that reign above the plains, this extreme environment lends itself to extreme weather. Long stretches of warm weather start in February, encourag-

Lilacs (*Syringa vulgaris* 'Henri Martin') at the Arnold Arboretum.

ing early leaf growth and bud break, only to be followed by sharp freezes in late April. These fluctuations are particularly hard on introduced flora during spring and fall, when biorhythms can be out of sync with steppe weather.

Due to one 14°F (-10°C) day in April, this year had turned out to be a particularly disappointing season for the lilac (*Syringa*) display. Still, there were some blooms. What had survived was fragrant and beautiful. And I realized what Erin must have already been thinking about—that for the first time in almost seventy years, we couldn't directly share this experience with our community. And although almost everything human was static, the phenological rhythm of the lilacs exists beyond COVID-19 time (and our psyches) as heralds of change and expectation.

"I'll go get some pics for you."

I moved through the collection, across the pathways of fescue, yarrow, clover, and flowering daisy, photographing the most hopeful, vibrant panicles. It was quiet, and I was alone in the collection at a moment when these shrubs would normally be stroked, sniffed, and praised thousands of times a day. I felt selfish and wondered if the lilacs were suffering from a lack of attention. They are gregarious creatures, attention seekers, but still, they felt dull: their scent weakened by my mask and their presence hazy through my constantly fogged sunglasses. Sometimes I feel comforted by our new personal protective equipment, but at that moment, I felt smothered and separated.

The standard protection that comes with being a gardener is, in itself, sometimes bulky, sometimes tactically empowering: hiking boots and knee pads for constant squatting, crawling, and walking; gloves to stop the earth from tearing my hands apart; and sunscreen, sunglasses, and a wide-brimmed hat, all to fight off the extra mile of solar radiation that we get in the high plains. The addition of the cloth mask was reassuring at first, during the colder days of March and early April, but on that hot May afternoon, it felt oppressive.

I finished photographing the blooms, put my phone in my pocket, and walked deep into a bed, hiding from the ever-present gaze of the mountains. I took my gloves off, pulled my mask down, and pushed my face in to fully smell their chemistry.

To breathe together, to share the air with plants, has always been our most fundamental of exchanges.

—Kevin Williams, Horticulturist

May 8

On the Friday before Mother's Day, I was working in the lilac collection at the Arnold Arboretum, double-checking it for any missed deadwood, overlooked weeds, and spillover mulch. As the caretaker for the collection, the upcoming Sunday would have been day zero for me—Lilac Sunday—the moment when all the work that I do comes to a head. Lilacs are the only plant that gets its own day of festivities at the Arnold, but unlike the 111 years of prior celebration, this year's event had been called off.

The lilac collection is nestled on one side of Bussey Hill, which rises in the center of the landscape. In early May, the collection looks endless as it wraps its way along the contours of the slope, with bursts of violets, purples, pinks, and whites. Normally, on Lilac Sunday—a Mother's Day tradition—thousands of New Englanders clamor to get their photo taken with the prolific flower displays and relish in the sweet aroma. Tour groups pack the roadway, enthusiastic and inquisitive. Merchandise and information booths are spaced accordingly. In recent years, an ensemble from the Boston Symphony Orchestra performed as guests made their way among the shrubs. But all the pomp and circumstance for this year was scrapped in light of the pandemic. I felt confused in my plight to steward the collection with all the fear and uncertainty that hung heavy in the community. Given that the Arnold Arboretum is one the few gardens to remain open while the rest of the world sheltered in place, I continued with "business as usual," so that some semblance of "normalcy" might be evident to any visitors who still relied upon the lilacs for their spring awakening.

The Friday before is usually a buzz of activity for me as I coordinate seasonal employees, interns from a local agricultural high school, and fellow colleagues to assist me in the final touch-up and presentation. I'm frequented with questions from the public about tips and tricks for lilac care, but this time I was isolated in my work. The hustle felt more imminent this time, not only because of the lack of extra hands but also because the preparations had taken a different slant. I always pamper and cater to the plants. I try my best to not distort a shrub's natural growth habit, but this time, my focus had changed to looking for pinch points in the collection. Where neighboring bushes might be funneling individuals too closely, I began pruning aggressively to widen corridors for greater social distancing, should the people we had asked to stay home decide to visit after all.

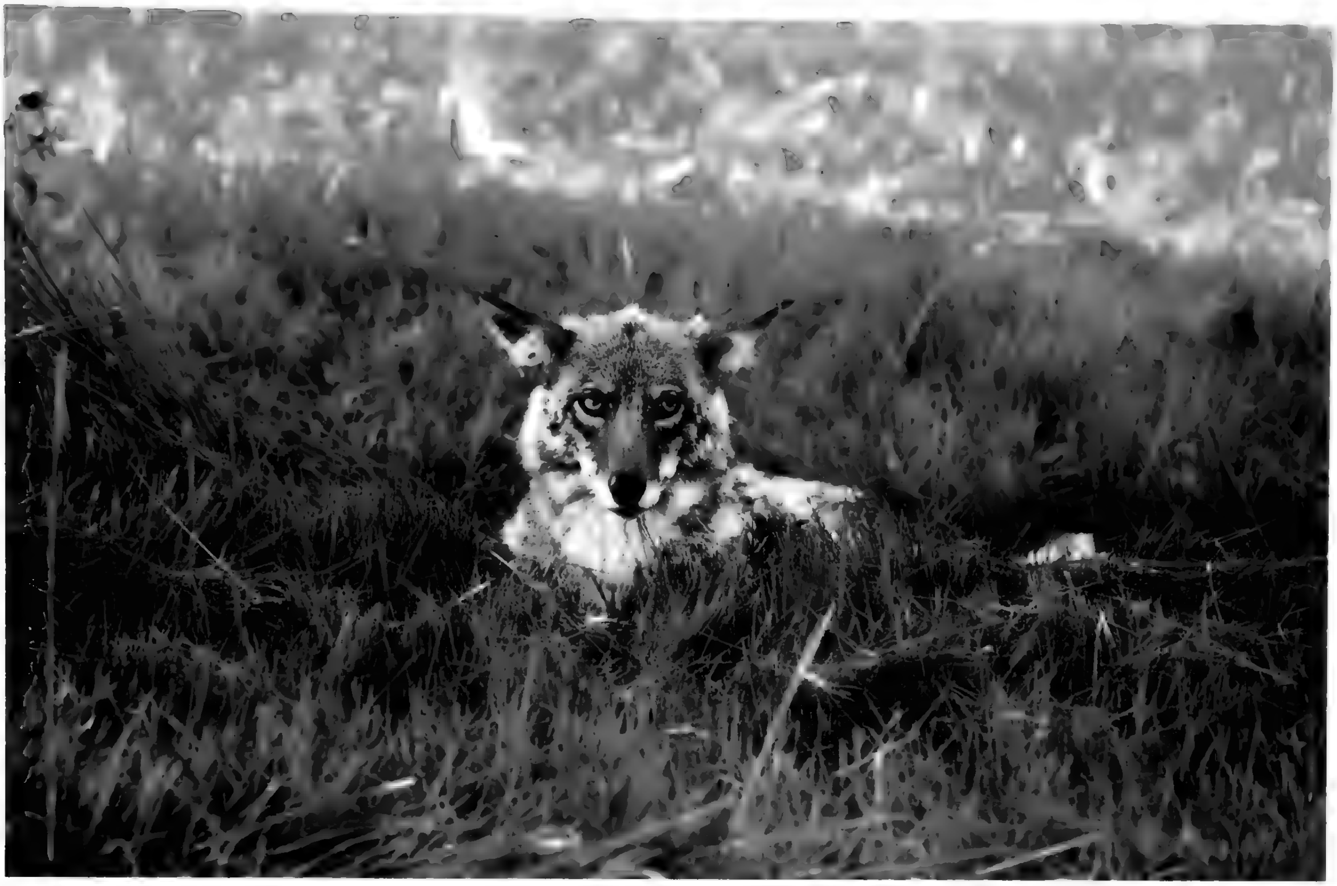
I also spray-painted white arrows on the sidewalk to request one-way traffic to limit potential exposure of those in the garden. I spent the afternoon posting normal signage ("Please don't pick the lilacs," "No picnicking at the Arboretum"), along with another, "Don't smell the lilacs." It felt strange and unfounded, especially for someone accustomed to removing hazards or providing a safe environment for visitors. But treating the lilacs like they could transmit the coronavirus was the necessary precaution given all the uncertainty. The day was a complete fog for me, literally, as I ran around with clouded safety glasses from my mask.

My instincts drew me in to pull the last-minute weeds and to cut out the hidden deadwood, but my main directive was to make visitors aware of the unseen dangers of what had always been a joyous day for celebrating spring, mothers, and the season of brighter days to come.

—Conor Guidarelli, Arboretum Horticulturist

May 12

On the morning of May 12, I walked rows of *Magnolia* hybrids at the Morton Arboretum, investigating buds on the trees, searching for signs of life. My work as the tree and shrub breeder at the arboretum builds on the legacies of others. I am less than four years into my career, yet I have tree selections in the pipeline and populations of progeny to select from.


Coyote at the Morton Arboretum.

These selections are the culmination of almost a hundred years of work spread over the careers of many individuals. Without this team that came before me, I would not have been here in this field of magnolias staring at the freeze-burned blossoms and emerging leaves. These hybrids had been developed over years by the late Dennis Ledvina, a much loved and highly respected magnolia breeder from the Green Bay area. Late-season freezes provide an opportunity to select for Ledvina's target traits—improved cold hardiness and delayed bloom time. The longer a tree holds off on developing its flowers or pushing out new growth, the better chance it will have of coming through these freezes unscathed.

I pressed buds between my thumb and forefinger, flagging trees whose buds gave way with a satisfying squish. While many gardeners lament when a late freeze occurs, a breeder reviews a weather forecast and then sits in anticipation for these moments, grateful for the gift Mother Nature has bestowed. The orange flagging tape was my signal to wield the mighty chainsaw and give the tree one final prune, a single cut at the base. Not all was lost; some would make it to see another winter. My dog, Maybelle, ran up and down the rows, delighting in the freedom of being penned into a fifteen-acre nursery. The nursery—wound round with electric fencing intended to keep out larger wildlife—is located on a southern edge of the arboretum, nestled between part of the taxonomic collection and a berm that buffers the sounds of an interstate that races through Chicago's western exurbs. Maybelle stopped short, leaned down to the ground and tentatively sniffed, inhaling the traces of other animals not yet seen.

My gaze followed Maybelle's: a female coyote stood thirty feet away, her belly hanging low and rippling with the life held within. After the Morton shut its gates on April 2, signs of coyotes have become widely apparent to anyone who accesses the grounds for essential work. The arboretum includes seventeen hundred acres of cultivated and curated collections, managed forests, and a planted prairie and savanna, which is more than enough room for coyotes and other wildlife. With only the familiar faces of arboretum staff present, these canine compatriots more readily emerge from their secret daytime hollows to observe us from

View from the Water Garden at Naples Botanical Garden.

PHOTO BY NAPLES BOTANICAL GARDEN

a distance. While not overly comfortable with us humans, the coyotes always exhibit some curiosity toward our existence. Perhaps this is a legacy of a recently retired staff member who spent fifty years living and working on the grounds with his family. August members of the staff have widely shared a story, with eyes twinkling, about how, years ago, this staff member once shared hot dogs with the first coyotes to establish their pack on these grounds.

Some decades from now, generations of magnolias and coyotes between, perhaps the great-great-great-granddaughter of this coyote will meet me in these rows one quiet spring day. As my thoughts wandered, I made eye contact with the coyote. She lingered momentarily, and as she walked away, I returned to Ledvina's magnolias.

—*Kim Shearer, Tree and Shrub Breeder and Manager of New Plant Development Program*

May 15

On an exceptionally muggy day in mid-May, I paused to take in my surroundings in the vast tropical collections at Naples Botanical Garden. I stood on the boardwalk over the Water Garden, a favorite spot that offers a panoramic view of the 170-acre property. Our Smith River of Grass, the garden's central spine and a replica of the Florida Everglades, stretched in front of me. The jungle-like Lea Asian Garden arose on one side, and the bright green performance lawn extended on the other. The garden had never looked so lush, I thought. The staff had laid fresh mulch, pruned, weeded, planted, taken out ailing trees, cleared areas for new displays. The colors this morning were extra vivid, a visual effect brought about by soot blown in from a wildfire burning in the Picayune Strand, well to our east. The waterlilies glowed in the light—mostly pinks, with a few yellows and purples. Beyond the pond, the cassia and poinciana lived up to their common names—golden-chained and flamboyant.

The smell of smoke made my stomach turn. Disasters loomed in my mind—the pandemic we are living through and the hurricane we survived in Florida not all that long ago. Irma tore a path through Naples in September 2017, shredding shrubs and downing trees. A local reporter described our garden as resembling "layers of tossed salad." Our visual paradise, which we had created from barren swampland less than ten years before, was ruined. The

winds had blown away years' worth of sweat and dirty fingernails.

I was wrong about the ruin. Volunteers and incredibly dedicated staff rushed to save the place. We rebounded like kudzu in Alabama. I'd argue we came back even better than before. When we first opened in 2009, we were a brand-new garden mostly focused on giving snowbirds something pretty to look at. We now have an incredible botanical collection, thanks to our amazing "plant nerds" and their desires for rare and unusual specimens.

But there is a difference in this new disaster. This time it's not the plants but the team that is battered and bruised and beaten. The plants look amazing, and if we could invite guests back in, their experience could not be better. But our gates closed in mid-March, not only to visitors but to our volunteers and even to our families. During the hurricane recovery, our staff and volunteers took afternoon breaks together to cool off and enjoy lunch, a daily ritual that lifted everyone's spirits. Who could lift us now? I thought about how my team looked during one of our weekly staff meetings. We had been able to keep everyone on, and I knew they were glad to be working, but I could see their exhaustion. They're the "tossed salad" this time, I thought. It's not just the dirty shirts and the unshaven faces, it's a lack of purpose that I worried about. Everyone was giving 100 percent, but for what? No one could see our beautiful oasis. No volunteer force was going to stride in to relieve the workload and share in the joy of creating something special.

But I shook off those feelings. We're adapting, just like nature taught us to do after Irma, when our collections rebounded and shone with the beauty I noticed that morning. We decided to take on big projects—like transplanting trees and dredging ponds—to give the team a break from the endless weeding and pruning and offer them the satisfaction of accomplishing major tasks. The gardeners, who are so used to interacting with the public, found other ways to communicate. They took photos, shot videos, and shared stories about the collections, broadcasting their work to the world online instead of welcoming guests to our property. They answered questions over Facebook instead of in person. Nothing can replace the in-person experience of a garden, but our horticultural creativity meant that all could share in the joy of something special—even during a crisis.

—Brian Galligan, Vice President of Horticulture

Epilogue

By the end of the spring, gardens and arboreta began to reopen. Bellevue Botanical Garden and the Arnold Arboretum were among the few whose grounds remained fully open throughout the early months of the pandemic. Ashton Gardens reopened on May 1, allowing visitors to catch the late-blooming tulips, and Filoli reopened on May 11. Attendees at both gardens were required to purchase timed-entry tickets. Filoli initially offered eight hundred tickets each day and later raised the number to fourteen hundred.

Prepurchased tickets became the modus operandi for gardens—a way of preventing attendance surges and of reducing interactions between visitors and staff at entrance bottlenecks. Denver Botanic Gardens reopened with a ticketed entry on May 22. The Morton Arboretum reopened to members on June 1 and to the general public on June 15. Phipps Conservatory and Botanical Gardens reopened on June 13, allowing a one-way path through the indoor conservatories. Longwood Gardens reopened on June 18, about three weeks before a massive corpse flower (*Amorphophallus titanum*) came into bloom. Due to state-mandated limits on guest capacity, the garden significantly expanded their evening hours so that more visitors could obtain tickets to experience the rare and short-lived bloom. Some visitors were relieved to find that the notoriously foul smell of the flowers was muffled by their masks.

Naples Botanical Garden fully reopened on July 6. New York Botanical Garden partially reopened on July 21. By the end of July, the Wakefield Arboretum had opened for limited reservation-only tours and special programs. The trajectory of the pandemic is far from over. Yet the innovations that have allowed gardens to reopen in person—and to connect with visitors online—will have a lasting impact, no matter what lies ahead.

One Green Earth

Peter H. Raven

While I was lying in bed in the spring of 1944, recovering from measles at the age of seven, my mother entered my bedroom and handed me a bright orange book: *Six Feet* by Ruth Cooper Whitney. Once I had taken a look, I couldn't put the book down. It presented simple stories, illustrations, and poems about different kinds of insects. Its stories were so engaging that I couldn't wait to rush outside and see the insects for myself—even though I'd paid no attention to them previously. In our garden, built on the sandy flats of the Richmond District in San Francisco, I could find and rear cabbage butterflies; discover Jerusalem crickets, earwigs, tenebrionid beetles, bumblebees, and other fascinating creatures; and begin to catch a glimpse of how they all fit together. I soon began making a collection of butterflies but then switched to beetles. I accumulated a collection of several boxes of these mounted insects, which my parents would proudly display when guests visited.

As the years passed, it turned out that this book, an otherwise ordinary gift from my mother, provided the first major step towards my career as a botanist and environmentalist—a career that would culminate with a forty-year tenure as director of the Missouri Botanical Garden. During that career, I would see our global understanding of biodiversity expand far beyond what was known when I first began collecting insects in my childhood backyard. Yet, over that same period, researchers have shown how humans have increasingly pushed the Earth towards an environmental breaking point. Even as researchers are racing to name and describe new species, they are simultaneously racing to save species from extinction.

The spring after starting my backyard explorations, I discovered the existence of the Student Section at the nearby California Academy of Sciences in Golden Gate Park. The group offered activities after school and on weekends, along with occasional field trips to the

RAVEN, P.H. 2020. ONE GREEN EARTH. *ARNOLDIA*, 78(1): 32–41

surrounding countryside. The students also received a degree of access to the scientific departments at the academy, and by the time I was ten, I had become a regular visitor to the Entomology Department. There, I could compare and identify my beetle collections with the help of friendly curators, especially E. C. Van Dyke, a world expert on beetles who was always encouraging.

By the time I was twelve, in the summer of 1948, I had begun to switch my interest to plants, largely because of a book called *Manual of the Flowering Plants of California*, by the great University of California botanist Willis Lynn Jepson. With the aid of this book, I could identify almost every plant species that I collected and determine whether there was anything unusual about the place I encountered it or the characteristics of the individual plants that I found. There had been no such book available for beetles. For plants, Jepson's *Manual* made the world seem small and knowable—as if the different species in the Bay Area were parts of a large puzzle for me to discover and piece together. In the academy's Botany Department, curator John Thomas Howell ("Tom" to almost everyone who knew him) took me under his wing and taught me more each I time I visited him. I started helping in the department as a volunteer in 1948, and later that year, I was hired for my first job, sorting new collections that had come from people working with Tom around the state.

My Early Exploration

While I knew, even as a child, that botanists were still discovering new species of plants around the world, I had always assumed that plants in the region of California where I grew up were already well documented. Generations of earlier botanists had studied the flora, and it seemed as though all of the plants had already been named and included. My first personal experience with a new species began when I was in my final year at high school. Harlan and Margaret Lewis, who were preparing a monograph of the attractive native plant genus *Clarkia*, showed up at the academy. They were reviewing herbarium specimens of *Clarkia*, and they had come across an unusual one that I had collected a couple of years earlier on a slope of serpentine rock in the San Francisco Presidio. They wanted to grow it for their research, but it took me two years to find the colony again. When I finally sent them the seeds, they invited me to work with them at UCLA the following summer, between my junior and senior years at Berkeley. Following that experience, it was only natural for me to begin graduate work with Harlan in 1957. The unusual *Clarkia* eventually proved to be an unnamed species: *Clarkia franciscana*—now a federally endangered species. While I maintained a lifelong interest in insects, I never looked back.

At UCLA, I prepared a dissertation on a group of desert plants that were, like *Clarkia*, members of the evening primrose family, Onagraceae. At the age of twenty-two, I married a girl I had met at the student section, Sally Barrett, and the following year, somewhat to the consternation of my graduate advisors, we had our first baby. We had our second child, Elizabeth, in 1960, while we were living in London, where I had a postdoctoral fellowship at Kew Gardens and the London Museum of Natural History.

We returned to California, and in 1962, after a job at Rancho Santa Ana Botanic Garden, I started what turned out to be a nine-year stint on the faculty at Stanford University. Fortunately for me, Stanford had a combined Department of Biological Sciences in which I had plenty of room to learn and grow in many aspects of the life sciences. Working with these colleagues, I could expand my research beyond its original emphasis on the classification of a particular group of plants and begin exploring topics with a broader and more theoretical footing.

My closest colleague at Stanford was Paul Ehrlich, an entomologist and population biologist who has remained a mentor and friend for life. Comparing our thoughts on plants and butterflies, we recognized that the caterpillars of some groups of butterflies fed almost exclusively on one related group of plants. In these

***Facing page:* A superbloom on the Carrizo Plain in California, with desert candle (*Caulanthus inflatus*) across the center of the image, the blue tansy phacelia (*Phacelia tanacetifolia*) in the foreground, and the hills beyond covered with hillside daisy (*Monolopia lanceolata*).**

PHOTOGRAPH BY ROB BADGER, FROM BADGER, R. AND WINTER, N. 2020. *BEAUTY AND THE BEAST: CALIFORNIA WILDFLOWERS AND CLIMATE CHANGE.* WINTERBADGER PRESS/CALIFORNIA NATIVE PLANT SOCIETY.

Monarch butterflies (*Danaus plexippus*) advertise their poisonous nature by their bright colors and thus warn birds to leave them alone or suffer the consequences. This group of butterflies takes the process of coevolution one step further, getting poisons from the milkweeds on which their caterpillars feed and using them to protect themselves.

cases, few other kinds of butterflies fed on the same groups of plants. Cabbage butterflies, for instance, which I had observed in my childhood backyard, were among a group of related butterflies that fed on plants in the mustard and caper families. Paul and I came to understand that the ancestors of these plants had, over time, evolved chemical defenses that deterred most other insects. Ancestors of the cabbage butterflies, on the other hand, had gained the ability to break down or resist those defenses, which meant a whole food resource was more or less exclusively available to them. Paul and I developed, published, and named this stepwise process coevolution, which turned out to be one of the most fruitful scientific discoveries that either of us ever made.

A couple of years earlier, my first Stanford graduate student, Dennis Breedlove had introduced me, through his fellow student and friend Brent Berlin, to a project that was being carried out in the Department of Anthropology. Professor A. Kimball Romney, one of the founders of cognitive anthropology and Berlin's graduate advisor, was working with colleagues to pursue various projects with the highland Mayans in the southernmost Mexican state of Chiapas. Together, the four of us conceived a project dealing with the names one group of these Mayans gave to the plants that grew in their area. Dennis moved to Chiapas for three years to carry out the botanical side of the study. We wanted to know what principles governed the way the Mayan community named their plants,

Gunnera insignis **was among the many wonderful new plants the author encountered while teaching a course for the Organization of Tropical Studies in Costa Rica in 1967.**

and what regularities we could find in comparing their system with those employed by groups from elsewhere. This Mayan community did not use a written language, and it turned out, this meant individuals only keep something like a few hundred plant names in their active memory. Within this system, they divided the kinds of plants most useful to them into many more categories than others.

When this project began, the plants of southern Mexico were unfamiliar to me. Challenged with a rapidly growing number of herbarium cases filled with such plants, I had to find ways to name them in order to fulfill my part of the project. I eventually solved this problem with the help of many specialists, especially Jerzy Rzedowski, a Holocaust survivor who had become and has remained for many years the doyen of Mexican botanists, and the taxonomist Rogers McVaugh of the University of Michigan. On my next major collecting adventure in the tropics, where I served as an instructor for the Organization for Tropical Studies basic field course in Costa Rica during the summer of 1967, I was able to ship all the specimens to Bill Burger at the Field Museum in Chicago. He found a number of undescribed species among them and was quite pleased with what he received.

Step by step, my interest in and knowledge about plants was expanding globally. Considering that my parents were living in Shanghai when I was born, and that my mother's grandfather arrived in California with his Irish family

MARY LOU OLSON, MISSOURI BOTANICAL GARDEN

Seiwa En, the Japanese Garden at the Missouri Botanical Garden, was designed as part of a plan to deepen community interest in this venerable institution (opened to the public in 1859) and, at the same time, to encourage an international outlook among St. Louisans.

(Breen) as a member of the 1846 Donner Party, a global perspective had always been central to my family narrative. It seemed only natural that this perspective should be extended to plants.

Research Coordination

The mid to late 1960s were a tumultuous time for America, and all the more so for me. My wife, Sally, died of a sudden and unexpected health problem at age thirty. Our two young children were nine and seven at the time. This personal tragedy was compounded by the national unrest. These years were unsettling and extraordinary. This broader sentiment has been expressed well by Joan Didion, in her essay "Slouching Towards Bethlehem," in which she describes the countercultural movement that had taken hold in San Francisco. "Once we could see these children, we could no longer … pretend that society's atomization could be reversed," she concludes towards the end of the essay. "This was not a traditional generational rebellion."

This period saw the Tet Offensive, the assassinations of Robert Kennedy and Martin Luther King, the riots and arrests at the Democratic Convention in Chicago, and eventually the Kent State shootings. Demonstrations became an everyday event on the Stanford campus, as they did at other universities throughout the country. All in all, I became deeply confused about where the world was headed and uncertain about what the future held for me and, indeed, for the world. In this period, I worked with Helena Curtis, another biology writer, in preparing the first edition of what turned out to be a very successful botany text, *The Biology of Plants*. I also remarried relatively soon, to Tamra Engelhorn, whom I had met on the Organization for Tropical Studies course in 1967. Notwithstanding these positive events, I remained deeply troubled about the future and, indeed, about the purpose of life.

My personal salvation came in the form of a sabbatical year in New Zealand, in 1969 and 1970. My intention in going there was to study the regional species of willow herbs, *Epilobium*,

the largest genus of the family Onagraceae. About a quarter of the roughly 160 species of the genus occurred in New Zealand and Australia, a strange fact considering the obvious New World origins of the family—why were there so many species of *Epilobium* in that part of the Southern Hemisphere? They were all herbs but widely varied in appearance. They gave the impression of having evolved relatively recently and rapidly in the varied habitats of the region.

As Tamra and I studied the *Epilobium*, we gradually regained our balance. New Zealand felt like a green paradise, and the people we worked with were level-headed, friendly, and helpful. One of them, Eric John Godley, the director of what was then the Botany Division at the Department of Scientific and Industrial Services, was of particular importance for me. We soon became fast friends. Nearly twenty years older than me, he calmly offered sound advice and joined us for enjoyable activities throughout our time in the country.

The theory that the position of the continents had moved over geologic time had been proposed half a century earlier by the German geophysicist Adolf Wegener. His theory was essentially validated in the years just before we reached New Zealand, and it opened important new ways to interpret the origins of the plants and animals in the region. I was quick to apply them to the patterns about which I was learning and to publish the results. For example, the ridge that included New Caledonia and New Zealand separated from Australia and Antarctica (then still joined) about eighty-five million years ago, and most of the plants in New Zealand (including *Epilobium*) reached their new home by blowing or floating across the intervening seas. In later years, I presented similar interpretations in a series of papers with my geologist friend (and former member of my doctoral committee) Dan Axelrod.

At our final dinner with Eric Godley, in the garden of his suburban home, he turned to me and asked what I was going to do next. He suggested that I might make the greatest contribution by emulating the great German botanist Adolph Engler, who, in the late nineteenth and early twentieth centuries, had led the production of the most important comprehensive works on plants, *Die Pflanzenfamilien* and *Das Pflanzenreich*. These works collectively described all the plants on Earth that were then known to science.

Returning to Stanford, I kept Eric's advice in mind: I looked for a pathway to become a leader in encouraging others to undertake major projects, rather than simply continue to do my own research. The need for synthesis became obvious to me, and it has turned out over the years that instead of the roughly 250,000 species of vascular plants we had thought existed then, the actual number approaches twice as many. With these broader horizons in mind, I applied for the open position of director of the Missouri Botanical Garden in St. Louis during my single year back at Stanford. As matters turned out, I was successful. There I soon realized my efforts in coordinating and enabling the studies of others were more important than the results I could achieve as an individual, regardless of how useful and interesting the results of my efforts might prove to be.

Global Collaboration

The Missouri Botanical Garden is the oldest public garden in the United States. I had visited several times earlier to consult its excellent herbarium. On my arrival in 1971, the garden's only major research project, and the only one it had ever conducted abroad, was the *Flora of Panama*, which was being published serially as exploration and writing proceeded. My experience in Chiapas had taught me that to inventory the plants of a particular area properly it was necessary to live there and work with them daily. It seemed logical to find parts of the world that were of particular interest botanically, not being studied in detail by others, and to concentrate there. We began to hire staff with the help of several grants from the National Science Foundation and the support that accompanied the increased local interest in the garden that we were building.

As the years went by, we were able to sponsor scientists to live in Nicaragua, Costa Rica, Ecuador, Peru, Bolivia, the Democratic Republic of the Congo, Madagascar, and Vietnam, and to form strong partnerships with a number of other countries. We established a branch office

WILLIAM MCNAMARA

Libing Zhang (Missouri Botanical Garden), Hong Deyuan (Beijing Institute of Botany), Peter Raven, William McNamara (Quarryhill Botanical Garden), and Fu Chengxin (Zhejiang University), on the summit ridge of Huangshan (Yellow Mountain), in Anhui Province, China, on April 6, 2008. The field trip occurred a few days after a meeting of the *Flora of China* Editorial Committee, held at Zhejiang University. Hong and Raven were coeditors of the forty-nine-volume project.

for studying African plants in the herbarium at the Muséum National d'Histoire Naturelle in Paris. Overall, these efforts led to the *Flora Mesoamericana,* a modern account of all plants between the Isthmus of Tehuantepec in southern Mexico and Panama; the revival of the *Flora of North America,* which covers the United States and Canada; national floras for many of the countries; and an online checklist of the plants of the Americas, a massive collaboration with institutions and researchers around the world that is headed by Carmen Ulloa Ulloa and Peter Jørgensen.

I also helped to start and then coedit the *Flora of China,* a forty-nine-volume work that treats the more than thirty-two thousand species of plants found in the country where I had been born. This important and personally enjoyable project lasted for some three decades and was the product of a major cooperative effort between dozens of institutions and hundreds of individual botanists. It brought the botanists of China, taking up their new opportunities as the effects of the Cultural Revolution receded in the late 1970s, into cooperative contacts with botanists all over the world. The volumes were jointly published by Academic Press in Beijing and the Missouri Botanical Garden.

Robert Woodson, the originator of the *Flora of Panama,* had told me in the course of a visit to St. Louis, back in 1961, that he thought they had accounted for nearly all of the species in the country. As our studies continued, however, we have reached the point where we now list approximately twice as many species from Panama as were known at that time. Everywhere botanists looked—not only in Panama, but in North America, China, and around the world—masses of new species turned up. Through this collective research effort, we were just beginning to grasp the magnitude of the Earth's biodiversity.

The Need for Conservation

When I was a young field biologist, in California, my studies were predicated on the assumption that the world would pretty much stay as it was. But in the 1960s, at Stanford, I started to

Tropical forests are being destroyed rapidly all over the world, as the 2011 clearing of primary forest for wood pulp in central Sumatra illustrates.

become aware of the rapidly increasing destruction of nature around the world and the need to do something about it. California's population was then less than a quarter of its present 40 million, and the global population was less than a third of its present 7.8 billion, headed for 10 billion by the middle of the century. I began to worry about the severe effects of DDT and other pollutants—Rachel Carson's *Silent Spring* appeared in 1962—and I came to understand Paul and Anne Ehrlich's emphasis on population growth as a factor driving the destruction of ecosystems globally. In an effort to influence the 1968 presidential election, Paul and Anne published *The Population Bomb*, a real wake-up call about problems that were starting to become obvious.

I was also becoming aware of the extensive destruction of tropical forests that was taking place; once I reached St. Louis this became a major issue for me in planning my personal activities and those of the garden. At the request and with the sponsorship of the National Science Foundation, I chaired a National Research Council study of priorities in systematic and evolutionary biology (Raven, 1974). By that time it had become obvious that the tropics were the most poorly known part of the Earth biologically and that the estimate for the number of species globally (then, with 1.5 million named, placed at 2 million) was much too low. Only five hundred thousand of the named species were tropical, yet two-thirds of the total number of species in well-known groups like plants and terrestrial vertebrates occurred there. It became clear that the actual number of species was at least 3 to 4 million—and now we would probably say 20 million, with only 2 million of them yet named. In view of these new estimates and the fact that we had a sense that major habitat destruction was going on in the tropics, we selected focused research in the tropics as a top priority. We knew a lot less than we thought we did.

Several years later, Bill Sievers, a program officer at the National Science Foundation, challenged me to head a study on setting specific research and conservation priorities in the

tropics. I felt that we first needed a more comprehensive understanding of the degree and rate of destruction that was going on in the tropics. This information would help us set the most critical priorities during our study. It seemed to me that the man for the job was Norman Myers, an imaginative English ecologist and conservationist. He had gone to Kenya in the British Colonial Service and stayed on after independence, working as a teacher, guide, photographer, and consultant. By the late 1960s, Norman had become one of the very first to recognize that we were entering a major extinction event and to write about it. To conduct the study of tropical forest destruction for us over an eighteen-month period, he visited all of the major tropical areas and many tropical forested countries, consulting a great deal of "gray literature" and conducting interviews. His report, published in 1980, proved to be a bombshell, documenting rates of deforestation much higher than were generally assumed at the time. It spurred us all to higher levels of action, given the urgency of the task facing us.

Once these relationships had become clear to me, I decided to devote a large part of my energy and available time to accomplish what could still be done while our present wealth of organisms and their ecosystems still exist. I had the opportunity to present the case for action at the American Association for the Advancement of Science annual meeting in Chicago in 1987. It was a large audience, and many people told me later that they had heard about the problem of mass extinction for the first time then (Raven, 1987). Even at the lower estimates of species numbers with which we began, we learned that for every twenty species of plants, animals, and other organisms in a given forest, nineteen were still unknown. So when an area of tropical forest is cleared, the overwhelming majority of species were disappearing without being documented by scientists. The problem was becoming generally obvious.

Today, more than a quarter of the tropical forests standing when the Convention on Biological Diversity was ratified, twenty-seven years ago, have been cleared. The rate is only increasing. Few researchers project that any substantial stands of tropical forest will remain by the end of this century. At the same time, the world climate is warming rapidly, with no strong international agreement in place to slow it down. Biologists can still hope to fill out a relatively complete picture of species numbers and distribution for vascular plants, terrestrial vertebrates, and a few other groups of organisms. But carefully constructed sampling protocols afford the only hope for learning much about groups such as nematodes, mites, and fungi, for which we have recognized fewer than one in a hundred species yet. At least a quarter of all species, most of them unknown, are predicted to disappear from the face of the Earth by the close of this century. What we find and save now will be all we can pass on to those who come after us. We have a moral obligation to do so. As University of Pennsylvania biologist Daniel Janzen has remarked, "If we don't save it now, we can't save it later."

Collective and Individual Action

When I was lying in bed recovering from measles at the age of seven, nearly eighty years ago, it would have been impossible for anyone, and certainly for me, to imagine the tremendously difficult problems we are facing now. Estimates by Global Footprint Network, based on United Nations statistics, reveal that human demand on natural resources in 1961 corresponded to about 73 percent of what Earth could renew at the time. Our demand has risen to 175 percent currently (Lin et al., 2018; Global Footprint Network, 2019). In other words, by July 29, 2019, humans had demanded as much of the Earth's resources as those ecosystems could regenerate in the entire year. Taking this depletion on a per-person basis, we find the averages in the United States, Gulf Countries, and Western Europe are the highest. In contrast, the averages within countries that lack ecological resources and purchasing power reflect very low demands, indicating extreme deprivation and difficult material prospects for their residents (Wackernagel et al., 2019). Huge inequities also exist within nations. Schemes for conservation imposed by wealthier nations tend to be massively unjust towards poorer nations, which have far fewer resources to devote to them than their wealthy counterparts. If the richer nations

PHOTOGRAPH BY CAMILLE PARMESAN, EDITED BY HENRY DOMKE

Pat and Peter Raven by the side of the rapidly receding Portage Glacier in Alaska, on a trip with scientists and Evangelical Christians to study climate change in early May 2007.

would partner with them and help financially, the schemes could work, but there is little sign of such mutual respect and the love that it would require to generate such help.

During my career, I have become convinced that only global collaboration and understanding can give us hope for sustainable life on Earth. Any such collaboration must be based on social justice and a spirit of love and understanding between people everywhere. Yet global success ultimately requires individual action, and it can exist only in a socially just world. Each of us must learn as much about the world, and especially about the poorer parts of the world, as we possibly can. We must live as sustainably as possible. We must vote for politicians who try to understand what's going on beyond their own short terms of office and who recognize the critical importance of arresting and then reversing global climate change. We must support the preservation of the species and ecosystems living today. We must also find ways to gradually lower our population to a level that the planet can support, instead of continuing to pretend that our global resource consumption doesn't matter. All of these actions are predicated on a fundamental need for us to find ways to love and appreciate one another. Our civilization is very young and vulnerable. Our ingrained habits of selfishness and competition were doubtless beneficial in a world where the total human population numbered in the hundreds of thousands, but they have become a sure pathway to destruction now. It is clearly time for us to act.

Acknowledgments

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Bur Oak Acorns

Each Year in the Forest: Summer

Andrew L. Hipp
Illustrated by Rachel D. Davis

I

Each year, for a few weeks in succession, I tell myself that we are done with spring. I think the chorus frogs have stopped singing for the year. Then they start up again. The sedges bloom in a flurry, anthers waving, and they die back. But then another wave arrives. Warblers stream through town and then are quiet. A few days later, I hear that a blue-winged warbler was lurking in the western suburbs. There is no clean joint between spring and summer.

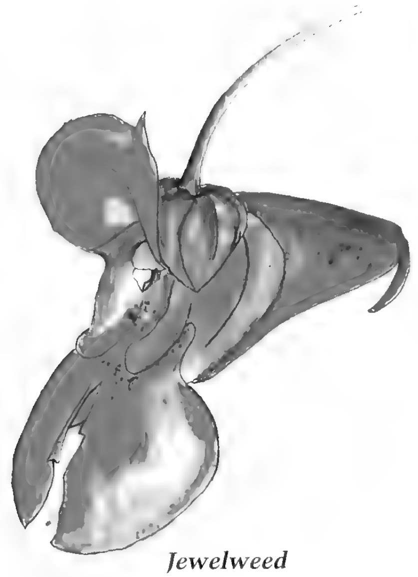
Still, near the beginning of June, the great waterleaf plants that emerged as blotchy, hairy leaves in early April become splendid with gauzy blue flowers. Dagger-like fruit columns sprout from the center of wild geranium flowers, arising from between the nutlets that develop at the bases of the petals. After a few weeks, they will catapult their seeds into the woods around them, then persist, irrelevant as the flowers fall to pieces. Sugar maple leaves unfurl. Toothwort begins yellowing; false mermaid becomes flattened and desiccated; the culms of straight-styled wood sedge flatten out as though they'd been stepped on by elephants. Leaves of wild leeks do the same. The forest prepares itself for the long run uphill to the solstice and over the crest to autumn.

HIPP, A.L. AND DAVIS, R.D. 2020. EACH YEAR IN THE FOREST: SUMMER. *ARNOLDIA*, 78(1): 42–51

In early June, hackberries and basswood leaves are still expanding. Oaks spill into flower as gray squirrels nip off the shoot tips and strew them across the forest floor. The door continues to close on spring for a few more weeks: Virginia waterleaf flowers nod at the bases of white oaks; great crested flycatchers and red-eyed vireos call at intermittent points along every walk in the woods; sedges of the second flush drop their fruits (nutlets wrapped in papery green perigynia that will see them through to fall), and the sedges of the third flush begin to ripen; woodland bluegrass spikelets gush with anthers. But spring isn't over until the last leaves are fully open and the holes close in the canopy. At that point, the forest floor becomes its darkest, and leaves of the white bear sedge abruptly broaden out. Summer spreads out before us with its long weeks of photosynthesis in full spate. Its progression of insect songs will take us through hot afternoons and humid mornings to the end of September.

Fireflies make their first flights near the beginning of June without any obvious chance to warm up and no training: they've only just pupated and emerged as adults. Still, they seem not to worry that their prospective mates might notice how raw and unpracticed they are. After a season of solitude as infants, after never having had a mating season at all, they mature, illuminate, and fly. They are nonchalant. They exhibit none of the uncertainty of young vertebrates, the stumbling fawns and warbling young white-throated sparrows, the clumsy great-horned owl babies. Instead, male fireflies execute aerial wooing dances whose precise choreography they are born knowing. These flights differentiate them by species. One flies a J-stroke. Another flies in dots and dashes. Meanwhile, the females sit in nearby shrubs and blink, drawing the males in.[1] I was once swinging a double-bladed weed cutter through the University of Wisconsin's Curtis Prairie near sunset and found that I had attracted the attention of a firefly, who flew in toward me and tried to attract the fancy of the bolts glinting along the joint between the handle and the blade. It was unsuccessful.

Mosquitoes are drawing blood by this time, bringing common nighthawks out into the open. I notice the nighthawks in the evenings when their splattery "peent," juicier and less strident than the woodcock's, draws my attention to the sky. They career around overhead with an agility that defies physics, banking almost as sharply as dragonflies, diving and pulling up, the white bands on their wings flashing. All the while, they are funneling insects into their mouths. Watching them fly, I cannot understand how a diet of small insects can sustain such energy. Their flight is ceaseless but for the rare times that I have seen one perching, roughly the size and shape of a large bread loaf, on the edge of a flat city rooftop. I sometimes hear a male roaring as he drops through the sky to impress a potential mate, wind booming through the primary feathers as he nears the bottom of his dive. This is the same time of year when I used to hear a close relative, the whip-poor-will, calling in wooded neighborhoods of the University of Wisconsin–Madison Arboretum on my late-night bike rides home from work.



Jewelweed

Wild Garlic

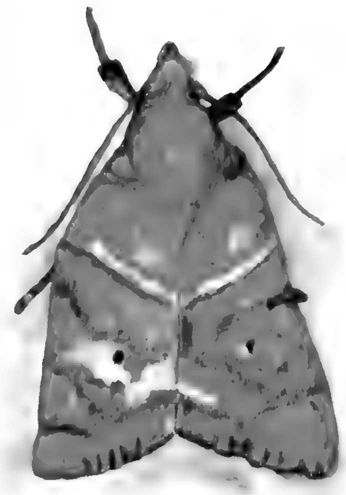
All through the month, I watch the juneberries slowly ripen. Many people grow them in their front yards and apparently have no idea that they are edible. When the berries finally become dark and soft and sweet enough to eat, they are delicious, and for a couple of weeks each June, I cannot walk past the vacant lot turned playground down our street without standing at the fence for at least a minute or two, eating berry after berry. They do not travel or store well, so I eat as much as I can while they are in season. As I do, I know without a doubt that we are in the midst of summer, though I couldn't tell you exactly when it started.

II

In the weeks leading up to the solstice, the great waterleaf petals fall, and their spidery inflorescences bear capsules that ooze pulpy white ovules when you pinch them. Jewelweed grows to chest height and produces mysterious translucent fruits that appear to have preceded the flowers. They are, in fact, the products of cleistogams, flowers that never open, in which the stigmas and anthers are closed in together and external pollination is excluded. They are the plant's answer to the risk of not getting pollinated. They explode in hand before I notice a single outcrossing flower. Beside them, leaves of the wood nettle sprout translucent galls that resemble tapioca pearls with a dark core. Inside each grows a gall midge, *Dasineura investita,* which I have probably seen in adulthood but never recognized.

Wild leek scapes poke up through the leaf litter, each tipped with an arrowhead-shaped hood. Some colonies emerge erect, others arched over and darkened on all surfaces. The flowering stalks sparsely map the extent of the dense swards of green foliage that grew fast in March and April, dissolving into the soil a couple of weeks before the scapes emerged, as the last holes closed in the canopy. There is no evidence of the leaves as the inflorescences swell against the hoods and tear through their sides. The inflorescences stand for a few days like fists raised above the leaf litter. The flowers open gradually, six papery tepals spreading beneath a congregation of stamens.


Ghost Pipes


Morbid Owlet Moth

The individual flower stalks grow as the flowers continue to open, so that at their peak, the colony of leeks is a cloud of airy white inflorescences.

Morbid owlet moths waft across the path and settle onto the undersides of last year's sugar maple leaves. The moths are similar to the faded maple leaves in color and value. Leconte's haploa moths flap their black-striped white wings like flags and settle on the shorter plants. Ebony jewelwing damselflies bumble along near creeks and at the edges of woodland marshes. They are so faithful to their habitat that when I see one, I know—whether I am in central Wisconsin, northern Illinois, or overseas[2]—that I am near water. They have a flair that I appreciate and a casual gait that I admire, flapping and gliding, bouncing between plants rather than vigorously taking out insects over open water. They seem to lack the ruthless efficiency of the other damselflies and dragonflies in the neighborhood.

Summer pricks the forest floor with light. The delicate white petals of enchanter's nightshade open at the tips of bristling ovaries. Wild garlic spathes open to reveal a cluster of bulbils atop a thin scape; flowers emerge from among the bulbs and turn toward the canopy on narrow stalks. Jumpseed that started the year as red-stained leaves low to the floor produce flowers roughly the size and shape of cooked orzo. Honewort flowers wink on like stars scattered between the major constellations and then give way to plump, rubbery fruits that smell of celery leaves. Ripened spikelets of fowl mannagrass shine at the tips of slender branches; I gather a handful and drizzle them along the side of the path, where they crackle like grains of couscous against the leaves. Seeds ripen to a glossy chestnut brown inside the wild ginger berries lying in the duff, each rimmed with an oily crest, an elaiosome, that is as delicious to ants as a fresh-baked roll is to a human. A dull, hairy capsule of the great waterleaf is nestled within the persistent calyx. But when I slough off the fruit wall with my fingers, the seeds inside lie wet and pearly white, reflecting sunflecks.

Then we hit the solstice. There is no more to see on this day than on any other, but we have a few extra minutes in which to see it.[3] For a month or

Dead Man's Fingers

Orange Mycena

so, the woods will trundle, pause, grow, and decompose. The long days will fill with cicada songs and greenery, the nights with clouds of fireflies. It is downhill now in both directions.

III

Through June and early July, the fruiting bodies of dead man's fingers (*Xylaria*)[4] curl from gaps in fallen tree trunks and protrude from the chipped trails. They are powdery gray and tipped with white at first, blackening as they mature. Collared parachute mushrooms (*Marasmius rotula*) sprout from decomposing branches and tree fragments. Their caps are gelatinous and crenate. Their ridged margins droop down over the tops of the stems like children's umbrellas that leave only torsos and legs visible as they walk the rainy paths. Orange mycena mushrooms (*Mycena leaiana*) sprout small colonies along the sides of rotting red oak trees. Trooping crumble caps (*Coprinellus disseminatus*) mass up in the wreckage of fallen branches, fragile and diminutive forests forming in the canopy's cemetery. White jelly fungus (*Ductifera pululahuana*) glistens at knee level. Ghost pipes emerge from the forest floor, white, with nodding flowers that look down toward their toes, feeding off the fungi that live with the tree roots. The forest is growing at full tilt, and already it is being devoured.

In Maple Grove Forest Preserve, there is a brown, spongy, decaying white ash trunk[5] that I regularly check for fungi. I found it bristling, on the Fourth of July last year, with what I thought were bright red, tiny toadstools. The caps were less than a millimeter in diameter, the stalks threadlike. A flat-backed millipede was crawling among this fur of filaments and pinheads. On the side of the log, a white, fleshy *Crepidotus*, a common wood-eating fungus, had emerged with a cluster of something that resembled tiny puffballs, a bit larger than mung beans. On a nearby log, the *Xylaria* were blackening at the tips.

I posted the "toadstool" photos to iNaturalist, a social networking site for sharing and discussing biodiversity photos. Within hours, I had heard from a Tasmanian naturalist[6] who observed that while the *Crepidotus* and *Xylaria* were fungi, the others were not. They were slime molds: *Cribraria* for the

"toadstools," wolf's milk (*Lycogala epidendrum*) for the "puffballs." I was surprised and delighted. In an afternoon, I'd found a whole new branch of the tree of life to watch for in the woods. I looked up the *Encyclopedia Britanica* entry on slime molds:[7]

> Science fiction did not invent the slime molds, but it has borrowed from them in using the idea of sheets of liquid, flowing protoplasm, giant voracious amoebae, engulfing and dissolving every living thing they touch. What fiction could only imagine, nature has evolved, and only their sharp dependence on coolness, moisture and darkness has kept the slime molds from ordinary observation, for they are common enough.

Two days later, I returned to the woods to find that I could now distinguish at least six slime molds by eye. In addition to *Cribraria* and wolf's milk, I found *Arcyria cinerea*, which looked like grains of rice suspended by threads; *Tubifera*, pincushions on the sides of the logs; an undifferentiated yellow plasmodium that might have been *Physarum* crawling over the surface of the log; and the aptly named dog-vomit slime mold (*Fuligo septica*) mounded up on logs stripped of their bark. I slapped the colony of *Cribraria*: spores rose and formed a fog around my hand, then drifted off along the length of the log.

After the slime mold sporing bodies disintegrated, the tree lay more or less naked. I have watched one end of the trunk crumble over the past year, trampled to the point that it now grades into the trail. The slime molds themselves didn't do this: they live largely on bacteria and fungi, not wood.[8] Ants have trailed through the sapwood and replaced xylem with frass; mycelia of chicken of the woods (*Laetiporus sulphureus*) have wound through the tree, devouring lignin, leaving the wood blocky and red; the roots of jewelweed and enchanter's nightshade growing on the top have tunneled into the wood; moss growing on the shady side has helped keep the tree spongy. Slime molds help with the mop-up.

When I returned this year, small patches of honeycomb coral slime mold (*Ceratiomyxa fruticulosa*) appeared on the side of the log by the first of July, along with wolf's milk. Then, on the third of July, as though on cue, a coat of *Cribraria* sporangia appeared on the flattened rubble pile along the path.

IV

By late July, many plants are scarred by insects. On the midribs of jewelweed leaves, translucent swellings conceal young gall midges (*Neolasioptera impatientifolia*), which grow as tiny yellow larvae inside each blister.[9] Elm-leaved and zigzag goldenrod that haven't come into flower yet are inscribed with meandering leaf-miner tunnels that begin small, thicken as the larvae inside grow, and often terminate in a hole. Leaf miners find white snakeroot as well. Other leaves are crisscrossed with slime trails that I suspect are left by slugs or snails, but the leaves often show no evidence of chewing or scraping damage. The broad, soon-to-become-evergreen leaves of white bear sedge begin to resemble subway maps, with routes scratched into

the mesophyll by leaf-miner flies (*Cerodontha* sp.), who follow the veins of the leaves longitudinally, tunneling in parallel before they veer diagonally to connect the paths.

Along a trail through the Morton Arboretum's East Woods, woodland sunflowers are packed as densely as a planted field. They flower in July, their brilliant yellow faces all turned intently southward, extending almost as far as I can see in the shade of the white oaks. Tall bellflower comes into bloom one day, and the blue flowers are high enough to stare me in the eye, a single style snaking out from the white-target center of each flower. Shining bedstraw scrambles along like baby's breath at ankle-height. False nettle erects columnar inflorescences that angle from the leaf nodes and look strong enough to hang a coat on. The filigree of wood nettle inflorescences signifies the end of one's opportunity to harvest the leaves for the year. Before this, they can be boiled and eaten, though in my experience they are bland. After this, I have been told, they become bitter. Perhaps this marks the beginning of the end of summer.

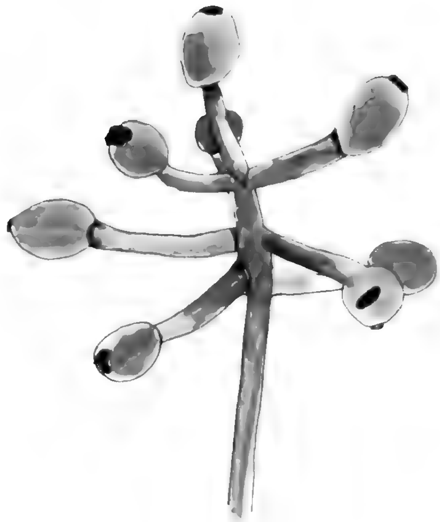
The interval from mid-July to the middle of August is hot and slow. I lose track of what is going on in the woods. I travel for a conference and come back to find that Solomon's seal berries are ripe; when I last looked, in early July, they had just broken out of the papery corollas that enclosed them. We leave on vacation, north to where Canada mayflower is in fruit and clubmosses are thick in the shady portions of the forest, and we return to find bottlebrush grass looking ragged, wild leeks beginning to fruit, clearweed in flower. Moonseed sprawls over fallen logs. This is the last month of summer before the boys return to school. The days spread out like a fog low over the field in the early morning, amorphous, hot, hard to pin down.

V

As summer draws to an end, sounds of the fields, woods, and suburbs mark my progression through each day. Between mid-July and early August, the robins relinquish their predawn singing to the cardinals. This changing of the guard always catches me unawares. Crickets stop singing as the sun starts to bear down. Cicadas and lawnmowers fill the midafternoon. Our family bustles around with supper, kitchen noises spilling out into the yard, then robins begin chuckling in the neighborhood. Cicadas give way to crickets about thirty or forty minutes after the sun sets. Crickets sing through the screen well into night as I sit by the window or by the fire in the backyard.

White snakeroot comes into bloom along trails and on the margins of woods by the baseball fields and parking lots. White baneberry fruits ripen, and the stigmas, shriveled at the tip, form a black eyeball. Inside are half a dozen glistening, wedge-shaped brown seeds embedded in pulp. Wingstem blossoms in the floodplains beneath the silver maples. Black elderberry ripens to sprays of small, dark berries. American pokeweed berries swell green and darken along one edge, filled with black, lenticular seeds. The brittle,

Woodland Sunflower

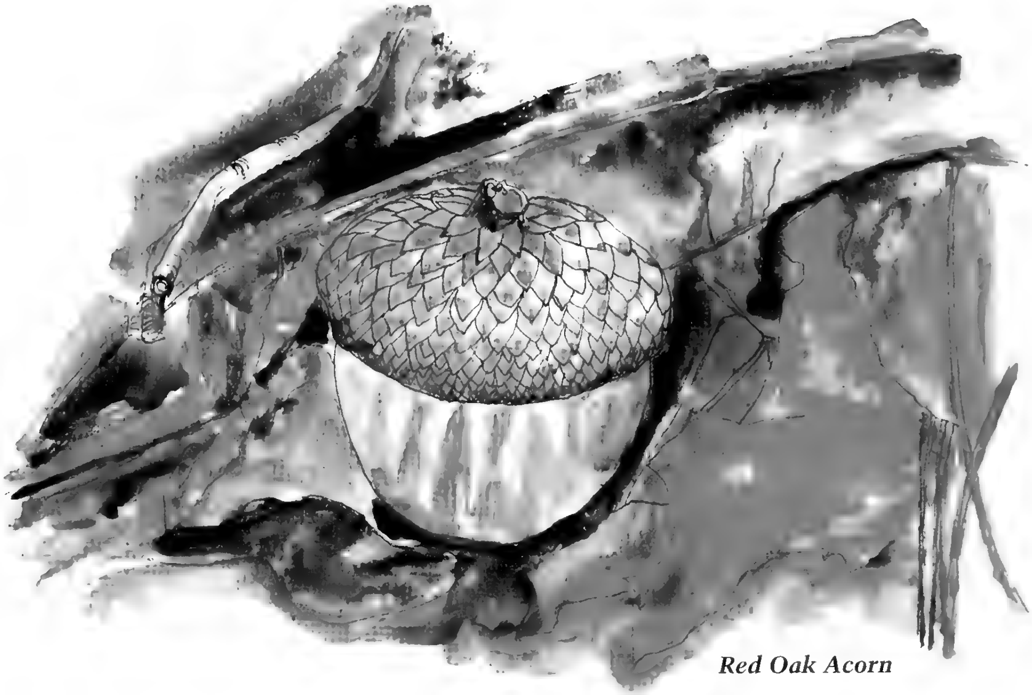


White Baneberry

jumpy, clingy fruits of the pathway species ripen. Lopseed fruits become completely reflexed. Jumpseed flowers enclose brittle fruits that have been hardening over the previous weeks and now spring at a touch. Fruits on enchanter's nightshade become bristly. Stickseed transitions from immaculate white flowers—five petals, no longer than a millimeter or so, each encircling a donut of tissue (the fornices) that extends up from the flower's throat—to stick-tights that will give you hours of work if you brush against a single plant while wearing a sweater.

Last year, red oak acorns littered the trails by the middle of August. I worried that they were falling too early, that they were all rotten, but biting a few open, I found mostly healthy cotyledons filling the shell. I floated out a sample at home, and about 50 percent sank, suggesting they were viable. But these were still at the outset of their journey, and not all would survive on the forest floor. Within hours of landing, they might be visited by insects who tunnel in and devour and fill the shell with frass before they depart, poor house guests. They might be preyed upon by molds and other fungi. The bur oak acorns swell through August and begin falling near its end, caps clothed in a ruff of kinked scales. Like the red oaks, they are in danger as soon as they land: pop the caps off of fallen bur oak acorns, and you often find writhing yellow larvae dying to get into the meat of the nut. The white oaks and Hill's oaks generally hang on a bit longer before they release their progeny to the ravaging insects, fungi, squirrels, and jays. Oak leaves and stems balloon up with galls of all types. By the end of the month, katydids rasp from the treetops.

There are no sutures between the seasons. We can flip over every log and scrabble around on the forest floor, and we'll find a multitude of signposts: false mermaid seedlings firing up, proliferations of mycorrhizae, cicadas



Red Oak Acorn

emerging, earthworms growing torpid as temperatures drop. With so much to choose from, we might as well start the forest year here, with the red oak acorns raining down to their various fates. As they bed down and some, at least, find a safe place to get a radicle into the ground, they are staking out a part of the forest that they may work for centuries. They have as strong a claim on the beginning of the year as anyone does.

Endnotes

[1] For a wonderful discussion of firefly biology and the importance of the dances to firefly taxonomy, read, Evans, H. E. 1968. In defense of magic: The story of fireflies. In *Life on a little known planet: A biologist's view of insects and their world* (chapter 6). New York: Dutton.

[2] In spring 2014, living west of Bordeaux with my family, my commute to work often included a bike ride from the train station at Gazinet through a sandy, spring-fed forest with a little creek. One morning, near the beginning of summer, I spotted what I thought to be the ebony jewelwing I had learned on the Lower Wisconsin River, and I saw it several times more during the last weeks of our stay. It turned out, though, that the species I knew, *Calypteryx maculata,* is endemic to Eastern North America. But the genus has Eurasian relatives as well. It seems most likely I was following the beautiful demoiselle, *Calypteryx virgo,* which lives along fast-flowing streams across much of Europe.

[3] Tim Dee writes of the day after the winter solstice: "The extra minute [per day] had nothing more to show than what was already present – it showed just a minute more of that. More light but, so, all begins again. Today, there was nothing else to see but there was one more minute to see it in." Dee, T. 2020. *Greenery: Journeys in springtime.* London: Jonathan Cape.

[4] I use the common name loosely here to refer to the fungal genus *Xylaria,* whose species are not easily distinguished from one another without microscopic study that I have not undertaken.

[5] I am indebted to my colleagues Christy Rollinson and Ross Alexander (at the Morton Arboretum) for their help identifying this tree from a wood sample.

[6] Lloyd, S. 2019. Tasmanian myxomycetes. https://sarahlloydmyxos.wordpress.com/

[7] Cohen, A.L.R. 1969. Slime molds (slime fungi). In: *Encyclopaedia Brittanica* (Vol. 20). Chicago: William Benton.

[8] Stephenson, S.L. and Stempen, H. 1994. *Myxomycetes: A handbook of slime molds.* Portland: Timber Press.

[9] For an image of the gall and the larva inside: Hatfield, M.J. 2013. Cecidomyiidae, jewel weed gall – *Neolasioptera impatientifolia*. Bug Guide. https://bugguide.net/node/view/741909

PLANTS REFERENCED

Acer saccharinum – silver maple
Acer saccharum – sugar maple
Actaea pachypoda – white baneberry
Ageratina altissima – white snakeroot
Allium canadense – wild garlic
Allium tricoccum – wild leek
Amelanchier sp. – juneberry
Asarum canadense – wild ginger
Boehmeria cylindrica – false nettle
Campanulastrum americanum – tall bellflower
Cardamine concatenata – toothwort
Carex sp. – sedge; there are other sedge genera, but these are the "true sedges" that dominate in our woodlands
Carex albursina – white bear sedge
Carex radiata – straight-styled wood sedge
Celtis occidentalis – hackberry
Circaea canadensis – enchanter's nightshade
Cryptotaenia canadensis – honewort
Floerkea proserpinacoides – false mermaid
Fraxinus americana – white ash
Galium concinnum – shining bedstraw
Geranium maculatum – wild geranium
Glyceria striata – fowl mannagrass
Hackelia virginiana – stickseed
Helianthus strumosus – woodland sunflower; though the colony I am referencing in the Morton Arboretum's East Woods may be referable to *H. decapetalus*
Hydrophyllum appendiculatum – great waterleaf
Hydrophyllum virginianum – Virginia waterleaf
Hystrix patula – bottlebrush grass
Impatiens sp. – jewelweed, touch-me-not
Laportea canadensis – wood nettle
Lycopodiaceae – clubmosses (various genera)
Maianthemum canadense – Canada mayflower
Menispermum canadense – moonseed
Monotropa uniflora – ghost pipe
Persicaria virginiana – jumpseed
Phryma leptostachya – lopseed
Phytolacca americana – American pokeweed
Pilea pumila – clearweed
Poa sylvatica – woodland bluegrass
Polygonatum biflorum – Solomon's seal
Quercus alba – white oak
Quercus ellipsoidalis – Hill's oak
Quercus macrocarpa – bur oak
Quercus rubra – red oak
Sambucus canadensis – black elderberry
Solidago flexicaulis – zigzag goldenrod
Solidago ulmifolia – elm-leaved goldenrod
Tilia americana – American basswood
Verbesina alternifolia – wingstem

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WHEELER, E. 2020. SPEAK, COTTONWOODS. *ARNOLDIA*, 78(1): 52–53

Speak, Cottonwoods

Emily Wheeler

In August 1895 and September 1896, the dendrologist John George Jack visited his hometown of Chateauguay, on the shores of the St. Lawrence River, near Montreal. By then, Jack had been working at the Arnold Arboretum for a decade. Director Charles Sprague Sargent had hired Jack as a manual laborer in 1886. The self-educated Jack rose over time to become a popular lecturer, a prolific plant collector, and an associate professor of dendrology at Harvard.

Jack returned to Boston from Chateauguay with seedlings of the eastern cottonwood (*Populus deltoides*). Fifteen members of accession 16611 were planted out near Peters Hill. In 1894, Jack had written a five-part series about the trees and shrubs growing near Montreal in the magazine *Garden and Forest*, which Sargent oversaw. In the final section, Jack described an impressive cottonwood growing near the Chateauguay River: "This tree is said to have been not much more than a sapling within the memory of some of the older inhabitants." Already, in 1894, its trunk measured more than five feet in diameter. This remarkable tree bore only pollen-producing male flowers (cottonwoods are dioecious), but the seedlings Jack collected may well have come from nearby. The seed capsules ripen in early summer and burst to release tiny seeds attached to cotton-like strands—nature's dust bunnies. A single tree can produce up to forty million seeds.

According to the Arboretum's records, Jack made plant collections near Chateauguay on a near-annual basis through 1912 (the year his mother, Annie, a well-known horticultural writer, died). Cottonwoods were a repeat interest. Another singular tree grew on an island in the mouth of the Chateauguay River, where a convent was then located. Jack had collected an herbarium specimen from this tree in 1889, and he would collect additional specimens from the same tree on at least four other occasions. The undersides of the leaves were more silvery than those of other cottonwoods, and Sargent came to recognize the tree as a hybrid between the eastern cottonwood and the balsam poplar (*Populus balsamifera*). In 1913, he named the hybrid in Jack's honor: *P.* × jackii.

Although Jack collected cuttings from the hybrid, none of the resulting trees are living today. As for the original accession of eastern cottonwoods, five remain, all at the juncture of the Peters Hill loop and the short oak-lined spur leading to Poplar Gate. These are large trees. Their silvery gray bark has matured into deep furrows. The trunk diameter of the largest is around three feet, which is impressive but not nearly the five-foot specimen that Jack had observed towering over the rich bottomlands.

In 1950, a year after Jack died at his farm in Walpole, Massachusetts, his name would appear in the *New Yorker*, in an essay by Vladimir Nabokov. (The essay was later adapted as the final chapter of Nabokov's memoir, *Speak, Memory*.) "I would like to have the ability Professor Jack, of Harvard and the Arnold Arboretum, told his students he had—of identifying twigs with his eyes shut, merely from the sound of their swish through the air," Nabokov wrote.

Nabokov had settled in the Boston area in 1941. Although he was an academic with a literature degree from Cambridge, England, he had, from boyhood on, a deep love of nature—especially butterflies. (He even worked with the lepidopteran collections at Harvard's Museum of Comparative Zoology.) Whether Jack and Nabokov met is unknown. Yet the writer spelled out examples of trees Jack's auditory keenness could identify: "hornbeam, honeysuckle, Lombardy poplar."

Leaves of the eastern cottonwood, like those of the Lombardy poplar (*Populus nigra*), have flattened petioles. Even the faintest breeze can cause the leaves to rustle. To some, the leaves of the eastern cottonwood shiver. If it's true that Jack could identify plants by their sound, perhaps, in the case of poplar, he was remembering the sound of wind caressing the big leaves of a mature cottonwood grove along the Saint Lawrence River—perhaps remembering the trees that drew him back again and again.

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